Hamology

amateur radio . . . . . the course

Second Edition

Brian Oliver ZL1OL

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SECOND EDITION UPDATE

March 1993

Page 1.1 Right column, second to last paragraph.
Delete this paragraph. There is now no restricted use of H.F. bands for new General licencees.

Page 12.1 Right column, Junction FET amplifier. Third to last paragraph.
Should read, ".....An amplified voltage is tapped off at the <u>drain</u> and fed out via C2."

Page 23.5 Right column, Third Schedule.
Initial licence fee and annual renewal fee is now $49.50.

Examination fees:	section A =	$15.00
	section B =	$10.00
	section C =	$13.50

Recount of marks is now $10.00

(All prices include GST)

Appen. II.17 Answer to question 26.
Should read option "D".

Amateur frequency allocations

Please replace with the following taken from the New Zealand Radio Frequency Service schedule no.3, Issue 1, Effective 4 June 1991:

Frequency band	Class
1800 to 1950 kHz (Notes 3 and 6)	General
3.50 to 3.90 MHz (Notes 1 and 3)	General
3.525 to 3.625 MHz (Notes 1 and 3)	Novice
7.00 to 7.10 MHz (Notes 1 and 2)	General
7.10 to 7.30 MHz (Notes 3 and 9)	General
10.10 to 10.15 MHz (Notes 1, 3, 6 and 9)	General
14.00 to 14.35 MHz (Notes 1 and 2)	General
18.068 to 18.168 MHz (Notes 1)	General
21.00 to 21.45 MHz (Notes 1 and 2)	General
21.10 to 21.20 MHz (Notes 1 and 2)	Novice and General
24.89 to 24.99 MHz (Notes 1 and 2)	General
27.12 MHz (Notes 4 and 7)	All Grades
28.00 to 29.70 MHz (Note 2)	General
28.10 to 28.60 MHz (Note 2)	Novice
50.00 to 50.15 MHz (Notes 3 and 8)	Limited and General
51.00 to 53.00 MHz (Note 3)	Limited and General
144.0 to 146.0 MHz (Notes 1 and 2)	All Grades
146.0 to 148.0 MHz (Note 3)	All Grades
430 to 449.75 (Notes 2, 3 and 9)	Limited and General
614 to 622 MHz (Notes 3 and 9)	Limited and General
922 to 927 (Notes 3, 4, 5, 10 and 11)	Limited and General
1.24 GHz to 1.30 GHz (Notes 2, 3 and 9)	Limited and General
2.396 GHz to 2.45 GHz (Notes 2, 3, 4 and 9)	Limited and General
3.30 GHz to 3.50 GHz (Notes 2, 3 and 9)	Limited and General
5.65 GHz to 5.85 GHz (Notes 2, 3, 4 and 9)	Limited and General
10.0 to 10.5 GHz (Notes 2, 3 and 9)	Limited and General
24.00 to 24.05 GHz (Notes 2 and 4)	Limited and General
24.05 to 24.25 GHz (Notes 3, 4 and 9)	Limited and General
47.0 to 47.2 GHz (Note 2)	Limited and General
75.5 to 76.0 GHz (Note 2)	Limited and General
76.0 to 81 GHz (Notes 2 and 3)	Limited and General
119.98 to 120.02 GHz (Notes 3 and 9)	Limited and General
142 to 144 GHz (Note 2)	Limited and General
144 to 149 GHz (Notes 2, 3 and 9)	Limited and General
241 to 248 GHz (Notes 2, 3 and 9)	Limited and General
248 to 250 GHz (Note 2)	Limited and General
275 GHz to 400 GHz (Notes 3 and 5)	Limited and General

Transmission of Morse code by Limited Grade operators is permitted.

A permit may be issued to individual amateur licencees allowing operation between frequencies 165 kHz and 190 kHz. Power is limited to 5 watts e.i.r.p.

Notes

1. These bands are available for use by all amateur licencees at times of natural disaster in connection with international relief operations, subject to approval of the Secretary.

2. The bands 7.0 to 7.1 MHz; 14.0 to 14.25 MHz, 21.00 to 21.45 MHz; 24.890 to 24.990 MHz; 28.0 to 29.7 MHz; 144 to 146 MHz; 435 to 438 MHz; 1260 to 1270 MHz (earth-to-space direction only); 2.4 to 2.45 GHz; 3.40 to 3.41 GHz; 5.65 to 5.67 GHz (earth-to-space direction only); 5.83 to 5.85 GHz (space-to-earth direction only); 10.45 to 10.5GHz; 24.0 to 24.05 GHz; 47.0 to 47.2 GHz; 75.5 to 81 GHz; 142 to 149 GHz, and 241 to 250 GHz may also be used for amateur satellite communications.

3. These bands are or may be allocated for use by other radio services. Amateur licencees may not use them in a manner which interferes with such other services.

4. The frequencies 27.12 MHz (±163 kHz), 925 MHz (±4 MHz), 2.40-2.45 GHz, 5.8 GHz (±75 MHz); and 24.125 GHz (±125 MHz) are designated for industrial, scientific and medical (ISM) purposes. Amateur licencees operating on allocations within these limits must accept interference from ISM equipment.

5. Allocated for use by amateur licencees on a temporary basis until further notice.

6. Until further notice the following spot frequencies may not be used: 1800kHz (±3kHz), 1860kHz (±3kHz), 10.130MHz (±3kHz). 1850kHz - 1950 kHz may not be used in a manner which interferes with navigation uses of those frequencies.

7. Telecontrol and telemetry operation only. Power output is not to exceed 5 watts mean power.

8. The band 50 - 50.15 MHz is allocated for temporary use. Operation is only permitted outside television programme hours.

9. These bands are allocated for use by other primary services, and Amateur usage is on a secondary service basis. Users of a secondary cannot claim protection from harmful interference from users of a primary or permitted service to which frequencies are already assigned or may be assigned at a later date.

10. Services particularly sensitive to other RF energy sources operate in adjacent frequency bands. Amateur licencees will be required to immediately cease transmission in the event of complaints of amateur interference to these services.

11. Power output is not to exceed 25 watts e.i.r.p. (Effective isotropic radiated power).

Contents

Special thanks *to my wife Carol who assisted with the typing and endured the many hundreds of hours I spent in preparing this course.*

Preface

Welcome to the second edition of Hamology, amateur radio....the course. Although these notes have their origin in 1980, when I was reluctantly ' talked into' tutoring a course in Kerikeri, it was not until 1987 when the first formal edition was published.

Three years later the radio theory requirements remain much the same but the radio regulations, the official body that administers them, and the supervision of the examinations, have all changed considerably.

For example, there is now no minimum age requirement, licences are no longer confined to British subjects, and third party traffic is allowed under many circumstances. Even Her Majesty's Government no longer has control over licensed radio stations in an emergency.

The Post Office no longer exists and has been replaced for our purposes by a new administration called "The Radio Frequency Service" which is part of a new "Ministry of Commerce".

The amateurs own association is now involved in the running and marking of examinations. Yes, things have certainly changed.

The first lesson has been up-dated and the regulation section, Lesson 23, has been completely rewritten. A further fifty questions and answers have been added in the appendix, all reflecting the latest changes in the regulation paper.

Well go to it and I look forward to working you on-the-air!

January 1990 *Brian Oliver, ZL1OL*

A note for fellow tutors - before each class is held, read the lesson over a few times to become familiar with it. Highlight points you wish to emphasise with a 'see-thru marker' or even jot down your own notes. Try to anticipate possible problem areas. Each class is normally two hours. I spend the first 30 minutes going over the previous weeks assignment that has been done as 'homework'. The remaining one and a half hours is used for the current lesson. A five minute 'break' during the lesson is a welcome relief for students to 'stretch-their-legs'.

During the class don't read all the lesson word for word, students can do this at home. Rather, use the headings as a guide as to what to cover with explanations and discussion. Relate bits of theory to practical experiences you may have had. Students enjoy hearing about real situations you have personally been involved in, especially if they are amusing.

Try to finish on time. Students often have other commitments and may have made arrangements to be collected afterwards. For every minute you go over, their concentration is being lost, and the valuable learning process is being undone.

I trust you find these course notes helpful and enjoy teaching and being a part of the dreams and aspirations of each student as much as I do.

Brian

LESSON 1

Introduction

Hamology

The science of amateur radio. It incorporates the knowledge and practical application of the laws of electricity, electronics and radio.

Amateur radio or 'ham' radio is a hobby with the privilege of not only sending and receiving messages via radio waves but doing so with equipment constructed by the amateur, if he or she so wishes.

The word 'ham' comes from the call letters of one of the first amateur radio stations. This was operated by the Harvard Radio Club, and in those early unregulated days, operators picked their own callsigns. In 1909 Albert Hyman, Bob Almy and Peggy Murray chose one using the first letter in each of their names- HAM. In 1911 Albert Hyman appeared before a committee hearing submissions on a new controversial Wireless Regulation Bill which, if it went ahead in its original form, would of closed down their small station. Subsequent nationwide publicity mean't the station HAM became the symbol of all other amateur stations. The support gained 'saved' amateur radio and today the association with HAM proudly lives on.

Within the realm of Hamology each amateur has their own idea as to what particular facet of the hobby is of interest, whether it be: building equipment and accessories, rag-chewing (long conversations), DX-ing (long distance contacts), satellite communication, contests, emergency communications, and so on.

Amateur radio is truly international and does not recognise any differences due to race, colour, religion or sex. Amateurs come from all walks of life and social status. Discussions on air don't have to be only on technical matters but may include other things of a personal nature.

Amateur radio in New Zealand

Amateur, or 'Ham' Radio, is established in New Zealand by act of Parliament with the "Radio Regulations" and is administered by the Radio Frequency Service (RFS) of The Ministry of Commerce. The RFS basically define amateur radio as being a service of intercommunication, self training and technical investigation by authorised people interested in radio on a personal level without commercial motives.

The very first non-commercial wireless regulations in New Zealand were gazetted on 30th April 1914, when permission was granted to the Canterbury University College covering constuction and use of receiving apparatus for experimental and scientific purposes. The first transmitting permit was issued on 5th December 1921 to Dr Robert Jack of Otago University. Radio regulations were gazetted in January 1923 to cover amateur, experimental, and broadcasting stations. On January 1st 1929 the prefix ZL was added to callsigns. In September 1939 amateur licences were revoked due to the outbreak of war and weren't re-issued until December 1945. In 1963 the non-morse certificate for operation above 144MHz was introduced.

Back now to the present day. Before becoming an amateur radio operator, some examinations must be passed to qualify for an "Amateur Operator Certificate of Competency". There are three classes of certificate: Novice, Limited, and General. Holders of one of these certificates may apply to the Radio Frequency Service for the corresponding licence which designates a 'call-sign' and authorises transmission on certain bands.

There is no age restriction for becoming a licenced amateur radio operator.

Privileges for each class-

Novice- Few bands, low power. Mostly N.Z. contacts.

Limited- Very High Frequency (v.h.f.) bands and higher. Excellent local & mobile operation.

General- All N.Z. amateur bands. World-wide.

(Details for all classes are given in Appendix III).

Entry can be made at any class although those that qualify for a General licence will be restricted in the use of some High Frequency (h.f.) bands for one year.

Examinations for all classes of certificate are currently held six-monthly on the first Saturdays of March and September. A special 'exam division' of the New Zealand Association of Radio Transmitters (NZART), the Hams own association, has recently been set up to run the exams. To ascertain examination location, application details, and any changes to the dates, please contact your local RFS office. (Addresses in Appendix I.2). Morse tests are currently held monthly for 'Up-grading'.

Certificate examination Requirements-

Class	Paper	Pass mark
Novice-	Section A	30%
	Section B	50%
	Section C	send & receive 6 wpm.
Limited-	Section A	50%
	Section B	50%
	Section C	not required.
General-	Section A	50%
	Section B	50%
	Section C	send & receive12 wpm.

Description of papers-

Section A- theory; a written paper with 80 multiple choice questions in the principles of electricity, electronics, and radio, and in the adjustment and operation of radio equipment used in a typical amateur station.

Section B- Regulations; a written paper with 30 multiple choice questions covering the radio regulations, operating procedures, service codes and abbreviations that are applicable to the amateur service.

Section C- Morse; send and receive, each for a period of 3 minutes contains both letters, figures and simple punctuation. Two errors are allowed in each element of the test, with 3 blemishes in the received copy being counted as an error. A blemish is regarded as any patched or otherwise imperfect character resulting from corrected guesswork or bad writing.

Sections A and B are sat together in one three hour examination.

Candidates for all classes sit the same papers for section A and B. Note the Novice pass mark is lower for Section A than the other classes.

A partial pass may be obtained in Section A or B and will remain valid through 2 full scheduled six-monthly examinations. Only the unsuccessful paper therefore need be sat within this period.

A partial pass may be obtained in Section C only if a pass is obtained in either Section A or B also.

Section C may be taken separately only where a pass is already held in Section A or B or both. For example to 'up-grade' from a Limited to a General Class.

When examinations have been passed for a particular class of certificate, a statement to that effect will be issued. It is planned that a 'certificate of success' will also be issued.

Novice & Limited Class licences may be held simultanously.

Further information is contained in Pamphlet RT4, available from the Radio Frequency Service.

NZART

Founded in 1926, the New Zealand Association of Radio Transmitters, (NZART), is a body formed by radio amateurs, independent of the Radio Frequency Service, and works for the common good of the 'Ham'. The reputation of NZART is very high and the relationship with the R.F.S., which recognises it as representative of all N.Z., is very good. Information on membership is obtainable from the "General Secretary, NZART Headquarters, P.O. Box 40-525, Upper Hutt". Services to members include:

1. Radio training scheme; regular slow morse transmissions.

2. Monthly "Break-In" magazine and an annual Call Book which contains a wealth of information; a must for every ham 'shack'.

3. Reduced prices on many excellent publications.

4. Eligibility to join local branch clubs.

5. Access to interest groups such as 'NZ Women Amateur Radio Operators', 'Amateur Radio Emergency Corps'.

6. Most importantly- representation to official bodies to retain the amateur bands and thus our hobby.

The course

1. This course will help prepare candidates for the Novice, Limited (non-morse) and General Amateur Operators Certificate of Competency examinations.

2. The lessons will deal mainly with theory although basic experiments will be performed. Regular practical morse practice is not given.

3. Assignments consisting of typical examination questions will be set each week as 'homework'. These will relate to the lesson just held. Answers to the questions are not given in these notes, but will be discussed in class at the start of the next lesson. Practical work of the students own choice will be encouraged, especially small kitset projects.

4. The recommended text is the "Radio Communication Handbook" published by the Radio Society of Great Britain.

5. A suggested programme for Tuesday classes leading up to the September 1990 examination is shown in Appendix I.2.

Electric shock

Can cause-

1. Unconsciousness with a) respiratory failure
   b) cardiac arrest.

2. Burns.

What To Do-

1. Turn off power; remove victim from electricity,

2. If unconscious- a) open airway, tilt head well back,
   a) check breathing- if absent perform resuscitation,
   b) check pulse- commence external cardiac compression. Ventilate the lungs in the ratio of two inflations to 15 compressions of the sternum. This is known as cardiopulmonary resuscitation or CPR. If another person is available one can do resuscitation and the other external cardiac compression in the ratio of one inflation to five compressions.

3. Get someone to call an ambulance or doctor.

4. Continue CPR until advanced medical help arrives and if breathing stabilizes, lay victim in the recovery position.

5. Check for burns; if practical immerse in cold water to relieve pain.

6. Wait for medical help to arrive.

Please note- classes of instruction in CPR using special training manikins are organised by the Health Education Officers of the National Heart Foundation. It is recommended that students try to attend one of these. Alternatively, attend a St Johns Ambulance Association first aid course which will include CPR instruction. An outline of CPR procedures is printed on the back page of the NZART annual callbook.

Learning Morse code

Morse operating is fun. Its almost magical, and like another language. Equipment can be very basic yet, in terms of performance, can surpass any other mode of communication.

Learning the morse code-

1. Memorise the code; say DIT & DAH, not dot & dash. Learn about four letters a day. The length of a dah is three times that of a dit. The separation between the parts within a symbol is one dit. The space between two symbols is three dits and the space between two words is equal to seven dits.

2. listen to: morse learning tapes,

   official slow morse transmissions, (on the 80 meter amateur band).

   competent morse sender. (Many radio clubs run morse classes).

Write and not print what is sent. Try to listen to several letters before writing them down. This 'writing-behind' technique will make copy at higher speeds easier and help overcome the 'plateau barrier' that is often experienced around 10wpm. Don't over-concentrate, if a letter is missed, forget it, and listen for the next one. The aim is to let the subconscious brain automatically recognize the morse characters.

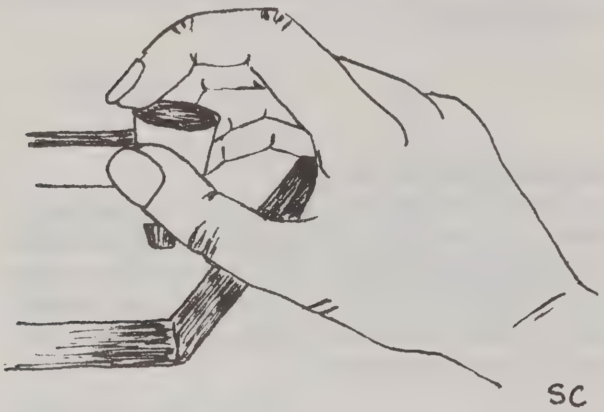
3. Practice a little at a time, but often, say, <u>every</u> day for approximately 15 minutes at a time. Practice is the only way to 'programme' the subconscious.

4. Two styles of learning:
   a) machine style- timing technically correct,
   b) fast style- letters and symbols at the 12wpm rate but spacing between them longer to give an overall slower speed. (This fast style is beneficial, for it not only gives one time to think, but also provides the proper sound of the letter itself).

5. Learn to recognise letters by overall sound, not individual dits and dahs.

6. Once reasonable receiving proficiency is achieved, say 8 - 10wpm, try sending. You are now thoroughly familar with how morse should sound. Use a good quality straight key at this stage, rather than a fancy 'bug' or electronic key.

Hold the key lightly with the thumb below the knob and the tips of the first and second fingers resting on top.



Relax the arm and lower the wrist to make the contacts close. Raising the wrist allows the key to return to normal.

To generate an appropriate sound a "code practise oscillator" needs to be used. This can be made up from a kitset and is relatively straight forward. Projects to be done at home are discussed in Lesson 6 and this would be an ideal one to do.

The Morse code

A	- —	N	— -
B	— - - -	O	— — —
C	— - — -	P	- — — -
D	— - -	Q	— — - —
E	-	R	- — -
F	- - — -	S	- - -
G	— — -	T	—
H	- - - -	U	- - —
I	- -	V	- - - —
J	- — — —	W	- — —
K	— - —	X	— - - —
L	- — - -	Y	— - — —
M	— —	Z	— — - -

dash (-)	— - - - - —
comma (,)	— — - - — —
fullstop (.)	- — - — - —
question mark (?)	- - — — - -
error	- - - - - - - -

Numerals-

1	- — — — —
2	- - — — —
3	- - - — —
4	- - - - —
5	- - - - -
6	— - - - -
7	— — - - -
8	— — — - -
9	— — — — -
0	— — — — —

Multi-choice questions

All questions in the Section A, (theory), and Section B, (regulations), are multi-choice. For each question only one of the options is correct. To gain experience in answering multi-choice questions, the assignments will consist of these. There are additional questions, with answers, in the appendix.

The multi-choice questions used fall into three main catagories:

1. Statement questions- a statement is started with a choice of different options to complete it. Read the question and the options carefully. Look for errors in the options, not the truth. All may contain an element of truth.

2. Definition question- refers to a standard definition or to a formula expressed in words. Do not look at the options. This can lead to confusion and doubts. Decide on a definition or formula, then compare with the options given..

3. Calculation questions- Note down all the details given in the question. Be careful though, sometimes more facts are given than are actually needed. Do not look at the options. The correct options listed often correspond with commonly made errors or incorrect use of formulae. Sketch a diagram if it helps, and do the calculation. Then compare with the options given.

Assignment 1

1. Which of the following should you do first for a person whose heart has stopped beating as a result of an electric shock?

   A. Check the person's airway before starting resuscitation;
   B. Send for a doctor;
   C. Force alcohol into the person to act as a stimulant;
   D. Administer 4 breaths in rapid succession.

2. You come across an unconscious person who has ceased breathing. Before commencing resuscitation you should first -

   A. Move him to a comfortable bed.
   B. Make sure the victim is not in contact with any live electrical conductors.
   C. Call an ambulance.
   D. Make sure the victim's mouth and throat are clear of obstacles.

3. In applying resuscitation to a person rendered unconscious by electric shock, one should -

   A. Clear the breathing passages before commencing.
   B. Administer a stimulant such as alcohol.
   C. Call a doctor before commencing.
   D. Cease resuscitation if the patient has not recovered after a half hour of application.

4. It is essential that there be no delay in giving cardio-pulmonary resuscition (CPR) to an electrocuted person. This is to prevent the victim suffering :

   A. Loss of lung capacity.
   B. Burns to the body at points of electrical contact.
   C. Irreversible brain damage.
   D. An elevated temperature.

5. In the event of an electrical shock in which the victim is thrown clear, resuscitation should be commenced on the patient :

   A. Immediately
   B. After a doctor has been summoned
   C. After checking the patients temperature
   D. After the patient has been wrapped in warm clothing.

6. As a result of a severe electric shock an amateur radio operator is lying on the floor unconscious, not breathing and has a weak pulse. What would you not do?

   A. Send for a doctor
   B. Loosen tight clothing around the neck
   C. Force alcohol into the person to act as a stimulant.
   D. Remove any obstruction from the air passage.

7. Which of the following should you do first for a person whose heart has stopped beating as a result of an electric shock :

   A. Check the person's airway before starting resuscitation.
   B. Send for a doctor.
   C. Administer 4 breaths in rapid succession.
   D. Wrap the victim in warm clothing.

8. Two people are administering C.P.R. The ratio of ventilating the lungs to external cardiac compression should be :

   A. 1 to 5
   B. 1 to 15
   C. 2 to 5
   D. 2 to 15

Questions 1 to 4 in this assignment are reproduced from past examination papers courtesy of RFS.

Maths and electricity

A complete understanding of maths is not essential but it helps to obtain those extra marks.

Fractions and decimals

22 can be written as 22.0 or 22.00 or $\frac{22}{1}$

5.6 can be written as 5.60 or 5.6000 or $\frac{5.6}{1}$

Fractions to decimals:
divide the bottom line into the top.

$$\text{one half} = \frac{1}{2} = 2\overline{)1} = 2\overline{)1.0} = 2\overset{0.5}{\overline{)1.0}}$$

$$\therefore \frac{1}{2} = \underline{0.5}$$

Decimals to fractions:
divide the decimal number by 1.

$$0.6 = \frac{0.6}{1} = \frac{6}{10} = \frac{3}{5}$$

Percentages (%)

Amount per 100.

$\frac{1}{2}$ or 0.5 is the same as say 50 units per 100 or 50 percent (%) as a percentage.

e.g. $\frac{1}{2}$ calculated as a percentage $= \frac{1}{2} \times \frac{100}{1}$

$$= \frac{100}{2}$$

$$= \underline{50\%}$$

conversely $25\% = 25 \text{ per } 100 = \frac{25}{100}$

$$\frac{1}{4} \text{ or } \underline{0.25}$$

Problem: find the new value if 33 is increased by 10%.

Do this in two steps,
i) find 10% of 33
ii) add this to the 33

Step i) $\frac{10}{100} \times 33 = \frac{1}{10} \times \frac{33}{1} = \frac{33}{10}$

$$= 3.3$$

Step ii) $33 + 3.3 = \underline{36.3}$

Prefixes

Used to avoid writing lots of zeros and so make calculations easier.

Giga (G) = x1,000,000,000 = $\times 10^9$ (9 zeros or ten to the power of nine).

Mega (M) = x1,000,000 = $\times 10^6$ (6 zeros)

Kilo (k) = x1,000 = $\times 10^3$

milli (m) = ÷1,000 = $\times 10^{-3}$

micro (μ) = ÷1,000,000 = $\times 10^{-6}$

nano (n) = ÷1,000,000,000 = $\times 10^{-9}$

pica (p) = ÷ 1,000,000,000,000 = $\times 10^{-12}$

Example i) : 1 kilometre is abbreviated 1km and is the same as 1×10^3 metres or 1000 meters.

Example ii) : 1200 millimetres = 1200×10^{-3} metres
= 1200 ÷ 1000 metres
= 1.2 metres.

Calculations with prefixes

1. Multiplication:

Problem i) 2×10^9 (2G) muliplied by 6.

a) long way:

$$\begin{array}{r} 2{,}000{,}000{,}000 \\ \underline{\times 6} \\ 12{,}000{,}000{,}000 \end{array}$$

b) short way: $2 \times 10^9 \times 6 = 12 \times 10^9 = \underline{12G}$
(multiplied whole numbers 2 and 6).

Note- When multiplying numbers containing more than one power of ten add the powers.

Eg. $1 \times 10^3 \times 10^6 = 1 \times 10^9$

Problem ii) 2×10^6 multiplied by 3×10^3

$= 2 \times 10^6 \times 3 \times 10^3$

$= 6 \times 10^6 \times 10^3$
(muliplied whole numbers 2 and 3)

$= 6 \times 10^9$ (added powers of ten)

$= \underline{6G}$

Problem iii) 2×10^6 multiplied by 4×10^{-3}

$= 2 \times 10^6 \times 4 \times 10^{-3}$

$= 2 \times 4 \quad \times 10^6 \times 10^{-3}$

$= 8 \times 10^6 \times 10^{-3}$
(multiplied whole numbers)

$= 8 \times 10^3$ (added powers of ten)

$= \underline{8k}$

2. Division:

Divide the whole numbers. For powers, subtract the bottom line from the top.

Problem i) $\dfrac{2 \times 10^6}{4 \times 10^6}$

$= 0.5 \ (\times 10^6) - (\times 10^6)$

$= \underline{0.5}$

Problem ii) $\dfrac{6 \times 10^3}{2 \times 10^{-3}}$

$= 3 \ (\times 10^3) - (\times 10^{-3})$

$= 3 \ (\times 10^3) + (\times 10^3)$
(a minus times a minus made a PLUS)

$= 3 \times 10^6$

$= \underline{3M}$

3. Addition

Add whole numbers if powers of ten are the same.

Problem i) 2k + 20k

$= (2 \times 10^3) + (20 \times 10^3)$

$= 22 \times 10^3$

$= \underline{22k}$

If powers of ten are not the same convert them to be the same.

Problem ii) 2k + 650

$= (2 \times 10^3) + (0.65 \times 10^3)$

$= 2.65 \times 10^3$

$= \underline{2.65k}$

4. Subtraction

Only subtract the whole numbers when the powers of ten are the same.

Problem i) 6M - 400k

$= (6 \times 10^6) - (400 \times 10^3)$

$= (6 \times 10^6) - (0.4 \times 10^6)$

$= 5.6 \times 10^6$

$= \underline{5.6M}$

Problem ii) = 1 metre - 200mm

$= 1 - (200 \times 10^{-3})$

$= 1 - 0.2$

$= \underline{0.8\text{metres}}$

Transposition

This enables a given formula to be rearranged so that any one unknown value in it can then be made to equal the known values. The unknown value is then easily able to be calculated.

The rule of thumb when doing this transposition or rearranging is that what you do to one side of the formula, you must be 'fair', and do to the other.

Problem i) transpose the equation to find the value of 'R'.

$$E = IR$$

$$IR = E \quad \text{(swapped sides)}$$

$$\frac{IR}{I} = \frac{E}{I} \quad \text{(divided both sides by I)}$$

$$\frac{\cancel{I}R}{\cancel{I}} = \frac{E}{I} \quad \text{(I's cancelled out)}$$

$$R = \frac{E}{I}$$

Problem ii) transpose to find 'L'.

$$X_L = 2\pi f L$$

$$2\pi f L = X_L$$

$$\frac{2\pi f L}{2\pi f} = \frac{X_L}{2\pi f} \quad \text{(divided both sides by } 2\pi f\text{)}$$

$$\therefore \quad L = \frac{X_L}{2\pi f}$$

Formulas may have to be 'cross-multiplied' at first:

Problem iii) transpose to find Ns.

$$\frac{Np}{Ns} = \frac{Ep}{Es}$$

$$Ns \times Ep = Np \times Es \quad \text{(cross-multiplied)}$$

$$\therefore \quad Ns = \frac{Np \times Es}{Ep}$$

(both sides divided by Ep)

Addition of fractions

Remember to find the lowest common denominator

Problem i) add: $\frac{1}{2} + \frac{1}{4}$

$$\frac{1}{2} + \frac{1}{4}$$

$$\frac{2+1}{4} \quad \text{.... lowest common denominator}$$

$$= \frac{3}{4}$$

Problem ii) find R, when:

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{10} + \frac{1}{4} + \frac{1}{5}$$

$$= \frac{1}{2} + \frac{1}{10} + \frac{1}{4} + \frac{1}{5}$$

$$\frac{10 + 2 + 5 + 4}{20}$$

$$= \frac{21}{20}$$

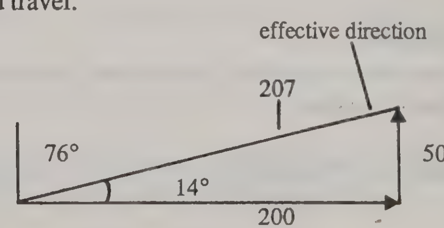
$$\therefore \quad R = \frac{20}{21}$$

$$= \underline{0.95}$$

Vectors

These allow complex calculations involving different values and differing angles to be made easily by drawing them to scale and taking measurements with a ruler.

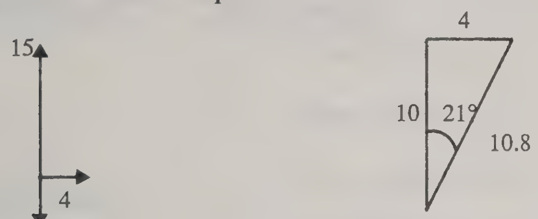
Problem i) A plane is planning to fly at 200 knots due east but will be affected by a 50 knot southerly. Show by vectors the direction and effective speed the plane would travel.



Effective speed = <u>207 knots</u>

Direction = 90° - 14° = <u>76°</u>

Problem ii) A ship would normally be steaming 15 knots due north but is being hampered by a head wind of 5 knots. Also there is a tidal movement in an easterly direction of 4 knots. Show by vectors the ships direction and effective speed.



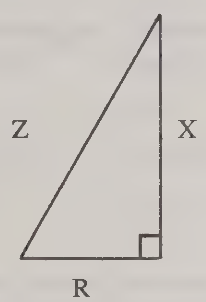
vector redrawn subtracting 5 from 15

Effective speed = 10.8 knots
Direction = 21°

Pythagoras theorem

This is a 'right-angle' triangle formula and problems like the above involving a right-angle can be calculated using it.

Pythagoras says the square of the hypotenuse is equal to the sum of the square of the two sides:



$$Z^2 = R^2 + X^2$$

As in the vector problem ii) :
let 'R' = 4 knots & 'X' = 10 knots

$$Z^2 = R^2 + X^2$$

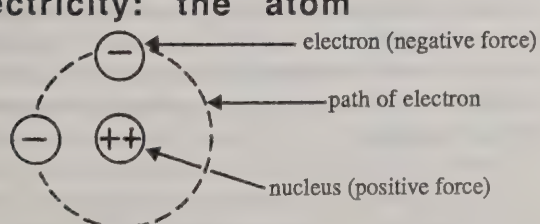
$$\therefore Z = \sqrt{R^2 + X^2}$$

$$= \sqrt{4^2 + 10^2}$$

$$= \sqrt{16 + 100}$$

$$= \sqrt{116} \quad = \underline{10.8 \text{ knots}}$$

Electricity: the atom

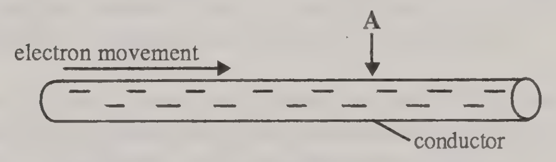


Conductors- materials where electrons are easily removed from their parent atom and are called free or valence electrons. Copper, aluminium, carbon.

Insulators- electrons not easily removed. Mica, glass, air.

Electric current

This is the movement of free electrons from atom to atom in a conductor. The rate of movement of these electrons past say point 'A' is called current flow and is measured in amperes or amps.



1 Amp = 6.28 $\times 10^{18}$ electrons / second

Analogy- *current is like water flowing through a pipe*

CURRENT: measured in amps (A)
formula symbol I

Electromotive force (e.m.f.)

This is the measure of the pressure or force available to move the free electrons from atom to atom in a conductor and is measured in volts.

A common way to generate or supply this force is by a chemical reaction in a device called a cell. The cell has two terminals; one called positive (+) and the other negative (-).
The two terminals have an imbalance in electron content, the negative terminal having more electrons than the positive one.

1 volt = the e.m.f. of a cell that is producing 1 joule of energy for every coulomb of charge.

Explanation: Joule- a measure of energy required to perform any work.

Coulomb- measure of quantity of electricity with current and time- referred to as 'charge'.

$$Q = I \times t(sec)$$

Analogy- *e.m.f. is like a pump providing pressure to push water through the pipe*

e.m.f.: measured in volts (V)
formula symbol E

Assignment 2

1. The mains voltage is lowered from 230volts by 10%. The new value is :

   A. 227.7 volts.
   B. 232.3 volts.
   C. 207 volts.
   D. 253 volts.

2. A distance of 25 kilometers is the same as:

   A. 0.025 metres.
   B. 25,000 metres.
   C. 0.025 millimeters.
   D. 25,000 millimeters.

3. An electronic component with a value of 0.018 microfarad is the same as :

   A. 1,800 picofarad.
   B. 18,000 picofarad.
   C. 180 nanofarad.
   D. 1,800 nanofarad.

4. When 13×10^3 is multiplied by 4×10^{-6} the result is :

   A. 52×10^{-3}

   B. 52×10^{3}

   C. 52×10^{-9}

   D. 52×10^{9}

5. The solution to $Z = \frac{m \times n}{m+n}$

   where $m = 200 \times 10^3$
   $n = 0.4 \times 10^6$ is :

   A. 0.1333×10^{-3}

   B. 0.1333×10^{3}

   C. 133.3×10^{-3}

   D. 133.3×10^{3}

6. When $P = I.E$, the correct value of I when the formula is transposed is :

   A. P.E

   B. P - E

   C. $\frac{P}{E}$

   D. $\frac{E}{P}$

7. A good insulator of electricity is :

   A. Carbon.
   B. Copper.
   C. Polystyrene.
   D. Gold.

8. A cell has an E.M.F. of 1 volt when it produces

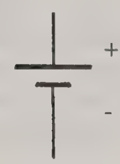
   A. 6.28×10^{18} electrons/second
   B. 6.28 joules of energy for every coulomb of charge.
   C. 1×10^{18} electrons/second.
   D. 1 joule of energy for every coulomb of charge.

LESSON 3

Direct Current

The cell

Circuit symbol:



Primary cells

These produce an e.m.f. naturally when manufactured and once 'flat' cannot be re-used.

a) Simple cell- zinc & copper in diluted sulphuric acid. E.m.f. created between two metals; zinc forming negative polarity in respect to copper. Not used in practice.

b) Leclanche, dry cell- carbon rod(+) in chemical paste in a zinc case(-). Very common.
e.m.f. = 1.5volts.

The zinc case, reacting with the paste, releases electrons and produces the e.m.f. Some zinc gradually dissolves in this process eventually causing the cell to leak. Life is limited.

Secondary cells

These do not produce an e.m.f. naturally but will hold one when 'charged' by passing a current through it in the opposite direction to the usual discharge current.

a) Storage cell, lead acid cell, accumulator- specially coated lead plates in electrolyte solution of sulphuric acid & water. Used in cars and many 'ham' shacks; has high current capability. e.m.f. when fully charged = 2.3v (1.9v when discharged).

During discharge the sulphuric acid gradually leaves the electrolyte by changing chemically and combining with the plates, but returns to the solution when recharged. The amount of sulphuric acid, being denser than water, will affect the overall density of the solution, (specific gravity). This can be measured with a 'hydrometer' to indicate the cells 'state-of-charge'. A low reading, (1.12), for a 'flat' cell and a high reading, (1.28), for a fully charged one.

For long cell life the electrolyte level must be kept topped up and not allowed to stand or operate in a low state of charge for any length of time. The amount of charging current is not critical so long as excessive gassing or a rapid temperature rise is not produced.

b) Nickel cadmium- nicad- completely sealed, require no maintenance. Can be used in any position and inside equipment. Easily stored. e.m.f. = 1.2v.

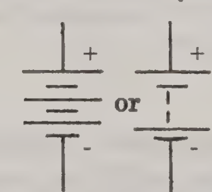
The e.m.f. stays at this voltage during use making its state-of-charge hard to determine until virtually flat whereupon its voltage suddenly 'dives'.

Recharging is done at a slow rate with care not to exceed specified current so to avoid excessive heat being generated and causing a build-up of gas pressure.

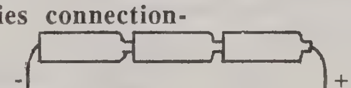
The battery

A group of cells connected together form a battery.

Circuit symbol:



i) series connection-

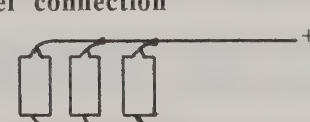


Total e.m.f. = sum of individual cell e.m.f.
Maximum I = same max. I of one cell

A 12v car battery has six cells in series giving an e.m.f. of 13.8v when fully charged. Mobile equipment is often rated for this voltage.

Note- a sealed battery made up of nicads should not be fully discharged for the most discharged cell may reverse in polarity and lower the battery's total e.m.f.

ii) parallel connection



Total e.m.f. = same as individual cell
Max. I = multiplied by the number of cells

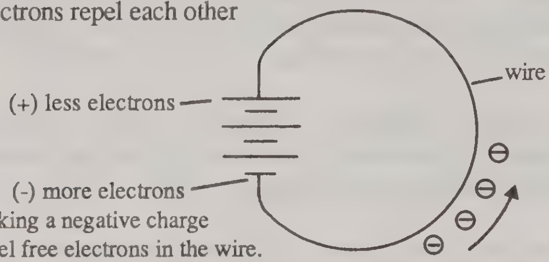
Battery capacity

The amount of electricity a battery is able to deliver. Measured in ampere-hours or milliampere-hours. It is normally calculated for a ten hour rate.

CAPACITY = I x 10 HOURS

The electric circuit

Like charges repel, unlike charges attract. Therefore electrons repel each other



making a negative charge repel free electrons in the wire. These free electrons are attracted to (+) terminal.

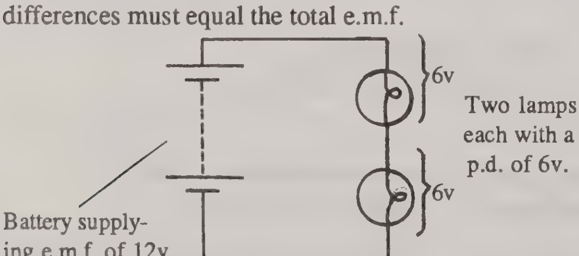
A flow of electrons occurs from atom to atom in the wire in a direction from the negative terminal to positive. Current flows and the circuit is said to be complete.

Direct current (d.c.)

Current that flows only in one direction due to an e.m.f. of fixed polarity such as that provided by the cell or battery.

Potential difference (p.d.)

In any circuit the total voltage drops or potential differences must equal the total e.m.f.



Resistance

The load put on the electron current which will affect its flow and is measured in ohms. Materials that provide resistance are neither perfect conductors or insulators but somewhere in between. The higher the value of resistance the more the opposition to the current.

1 Ohm = that resistance that will allow a current of 1 amp to flow when an e.m.f. of 1 volt is applied.

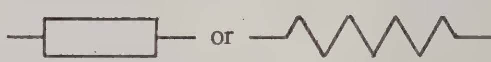
Analogy- *a paddle that is turned by the flow of water.*

RESISTANCE: measured in ohms (Ω)
formula symbol R

Resistors

a) **Fixed:** These are devices made especially to provide resistance in circuits. They come in different amounts of resistance and physical sizes and are usually colour coded with their value.

Circuit symbol:

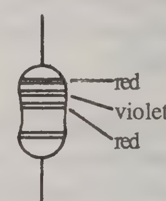


COLOUR	FIGURE (1st & 2nd bands) ZEROS (3rd band)
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

If 3rd band is gold = x 0.1, if silver = x 0.01

4th band (value tolerance): Gold ±5%, Silver ±10%

Problem: What is the value of this resistor:

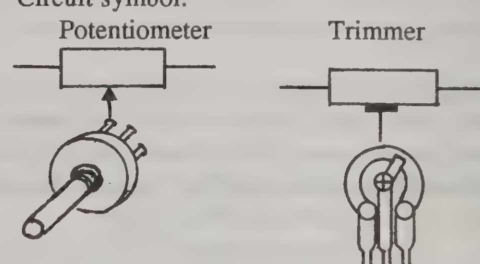


1st band = red = 2
2nd band = violet = 7
3rd band = red = two zeros (0 0)

therefore: value is 2700Ω or 2.7kΩ.

b) Variable

Circuit symbol:



i) Resistors in series:

$$R_T = R_1 + R_2 + R_3$$

ii) Resistors in parallel

1) for only two-

$$R_T = \frac{R1 \cdot R2}{R1 + R2}$$

2) three or more-

$$\frac{1}{R_T} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

Conductance (G)

The reciprocal of resistance and is measured in siemen or mho's.

$$G = \frac{1}{R}$$

<u>CONDUCTANCE:</u> measured in siemen or mho's
formula symbol G

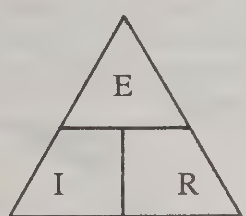
Ohms law

In any circuit or resistance the voltage is directly proportional to the current flowing through that resistance or circuit provided the temperature is held constant. This relationship is expressed:

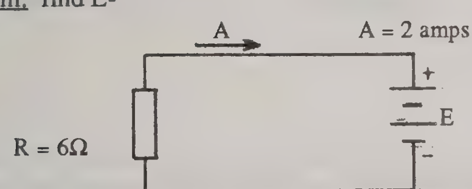
$$E = I.R$$

this may be transposed: $I = \frac{E}{R}$ and $R = \frac{E}{I}$ and

can be remembered by this triangle:



<u>Problem:</u> find E-

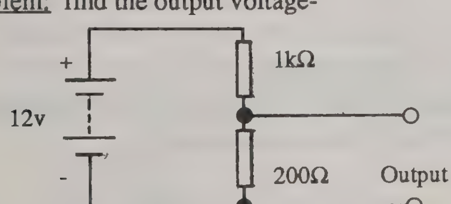


$E = I.R = 2 \times 6 = \underline{12v}$

Voltage divider

The potential difference across each resistor will depend upon their value with respect to each other. A wanted voltage can be 'tapped' or divided off.

<u>Problem:</u> find the output voltage-



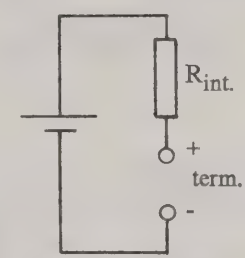
First find R: $R_T = R_1 + R_2 = 1.2 \times 10^3\Omega$

Next find I through resistors: $I = 10 \times 10^{-3}A$

Lastly, find E across 200Ω resistor: $E = IR = \underline{2v.}$

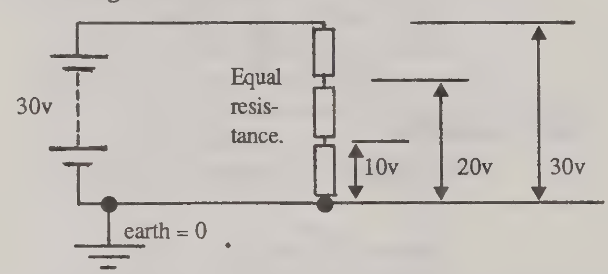
Battery internal resistance

All batteries have some small amount of natural resistance 'inside' them. This is only a problem if high current is drawn, in which case this internal resistance drops voltage and reduces that at the terminals. When batteries run down this internal resistance slowly rises, also giving a lower terminal voltage.

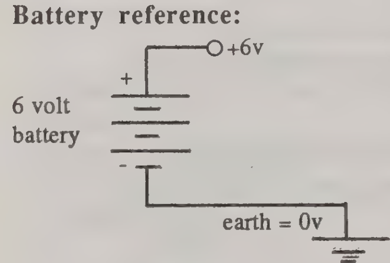


Circuit reference point

Voltage measurements made, and voltages in circuit diagrams, are normally in respect to a common point or line. This is referred to as earth which is said to be at zero (0) volts. This earth line is therefore the reference for voltage measurements unless stated otherwise.



Battery reference:



Note- we do not have +6v and -6v making 12v but the (-) term. we say is at 0v and the (+) term. is at +6v.

Power (P)

Rate at which work is done and energy used. Measured in Watts.

$$1 \text{ watt} = \frac{1 \text{ joulé}}{\text{sec}}$$

Power shows itself in the form of heat, and this energy is said to be 'dissipated'

$$P = E.I$$

Resistors come in different physical sizes dependent upon their power rating.

Analogy- a paddle wheel delivering energy to its shaft.

<u>POWER:</u> measured in watts (W)
formula symbol P

Power and Ohms law

$P = E\,.\,I$ or $P = E.I$

$= I.R\,.I \quad (E = I.R)$

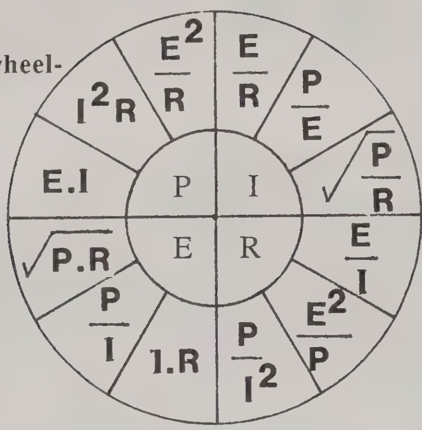
$= I\,.\,I\,.\,R$

$$P = I^2 R$$

$= E.\frac{E}{R}$

$$P = \frac{E^2}{R}$$

The wheel-

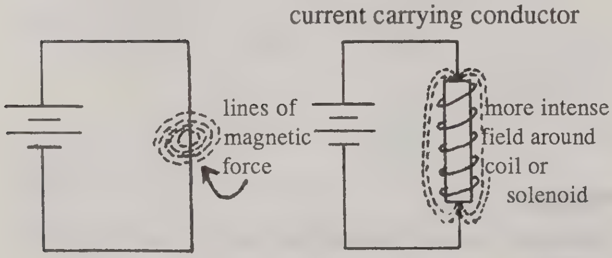


The switch

Circuit symbol:

Magnetism

Properties: attract ferrous materials
line up North/South if pivoted
Induces magnetism into other ferrous materials
like magnetic poles repel, unlike attract
magnetic field is set up around a current carrying conductor



Flux (Ø)- the magnetic field

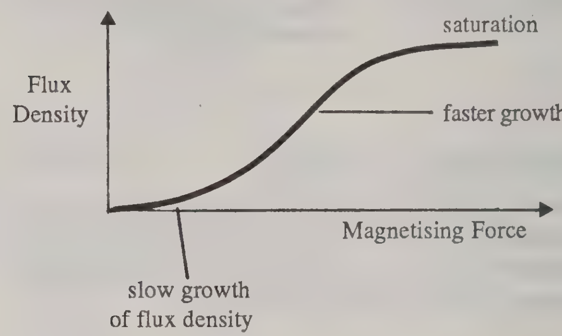
Flux Density (ß)- the concentration of the magnetic field and is proportional to the current flowing in a conductor.

Magnetising force (H)- that force provided by the current flowing through a coil.

Permeability (μ)- the relationship between the magnetising force and resultant flux density of a coil in free space.

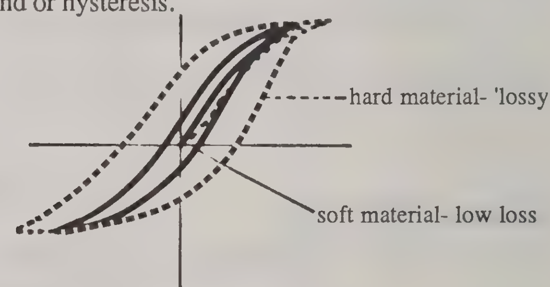
Relative Permeability (μr)- the ratio of increase over μ if a core is now placed inside the coil.

Hysteresis - the lagging behind of the resultant magnetism to that of the applied magnetising force.



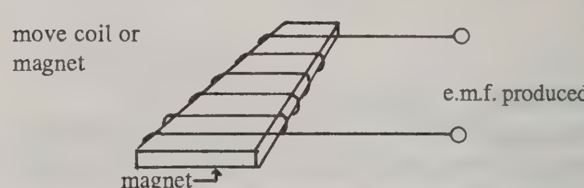
Hysteresis loop

A plot of flux density when the magnetising force is increased from zero in a positive direction and then reversed in a negative direction. Notice the lagging behind or hysteresis.



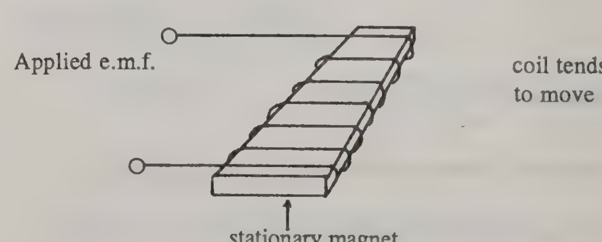
Generator principle

If a conductor moves in a magnetic field an e.m.f. will be induced in the conductor.



Motor principle

If a conductor which is carrying current is placed in a magnetic field a force will act upon it.



Assignment 3

1. Which of the following relationships describes Ohm's law?

   A. Current is equal to the resistance times the voltage.
   B. Resistance is equal to the voltage divided by the current.
   C. Voltage is equal to the resistance divided by the current.
   D. Current is equal to the resistance divided by the voltage.

2. A 3 ohm resistor and a 2 ohm resistor are connected in parallel. This combination is connected in series with a 4 ohm resistor. If the whole network is connected across a 5 volt supply, the amount of current flowing in the 2 ohm resistor is approximately how many milliamperes?

   A. 390.
   B. 400.
   C. 580.
   D. 1110.

3. The current that would cause 10 watts of power to be dissipated by a 40 ohm resistor would be :

   A. 0.5 amperes.
   B. 4.0 amperes.
   C. 20.0 amperes.
   D. 400.0 amperes.

4. Three 10 ohm resistors are connected in series with a 100 mA current source. Resistor dissipation ratings are eighth, quarter and half watt respectively. Which resistor, if any, runs hottest?

   A. Eighth watt.
   B. Quarter watt.
   C. Half watt.
   D. All equal.

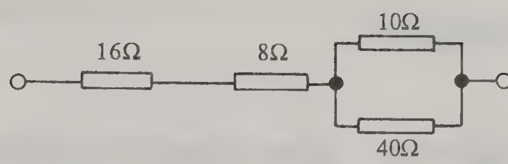


Figure 1

5. Which resistor in the combination shown in Figure 1 would generate most heat when a voltage source is applied?
   A. 8 ohms.
   B. 10 ohms.
   C. 16 ohms.
   D. 40 ohms.

6. The nickel-cadmium cell has the advantage over lead-acid cell in that :

   A. It can be discharged to zero volts.
   B. Its state of charge is easily assessed.
   C. It can be recharged effectively after a long period of disuse.
   D. It has a higher cell voltage.

7. Charging sealed Nicads at high rates is not recommended because as they reach the fully charged state :

   A. Electrolyte will be converted into corrosive material.
   B. Products of decomposed water may build up high gas pressure.
   C. The high temperatures will melt the electrodes.
   D. Thermal expansion of the electrolyte will cause the cell to explode.

8. Four resistors colour banded from left to right are described below. Which has the highest resistance?

   A. Yellow violet orange silver.
   B. Orange red red silver.
   C. Red red orange gold.
   D. Brown black red gold.

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

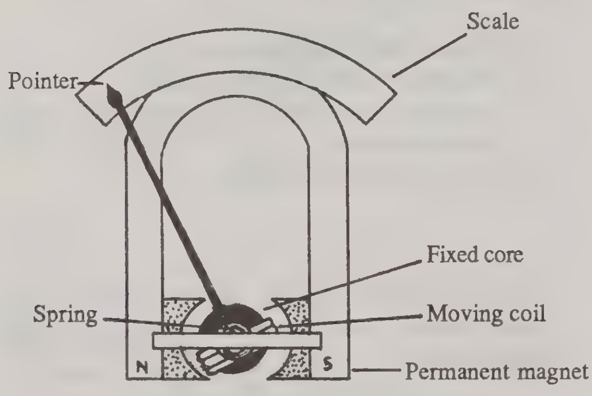
LESSON 4.

Basic measurements

To measure current, use an 'ammeter'
To measure voltage, use a 'voltmeter'
To measure resistance, use an 'ohm-meter'.

The 'heart' of these meters is traditionally the "meter-movement".

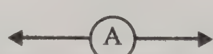
The meter-movement



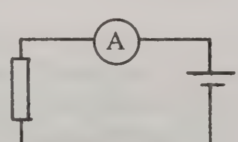
A current flows through the coil setting up its own field which then interacts with the fixed field from the magnet. The coil with pointer attached, moves due to the 'motor principle'.

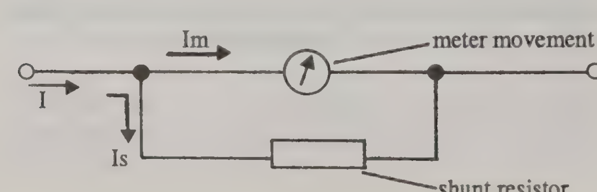
The ammeter

Circuit symbol:



The ammeter is placed IN the circuit and consists of a meter movement and 'shunt' resistor. The shunt allows measurement of heavier currents by providing another path for the majority of the current.

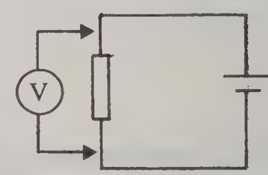


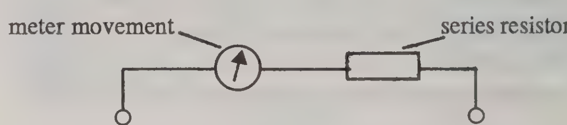


The voltmeter

Circuit symbol:

The voltmeter is placed ACROSS the part to be measured and consists of a meter movement and 'series' resistor.





Sensitivity- the amount that a voltmeter 'loads' the circuit under measurement and is given in 'ohms/volt.

Problem: a meter movement in a voltmeter has a full scale deflection, (f.s.d.), of 50μA. What is the voltmeters sensitivity?

$$R = \frac{E}{I}$$

(sens. is per 1 volt)

$$= \frac{1}{50 \times 10^{-6}}$$

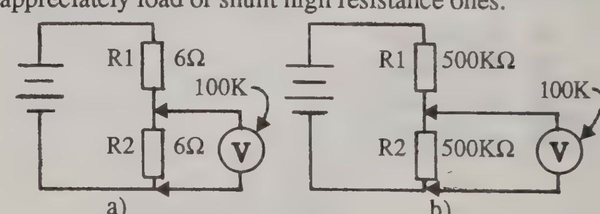
$$= \underline{20{,}000 \text{ ohm/volt}}$$

A low sensitivity, (small ohm/volt), will in some cases give a misleading reading.

For example: A 10 volt voltmeter has a sensitivity of 10,000 ohms/volt. Therefore its total resistance will be:

$10{,}000\Omega \times 10 = 100K\Omega$

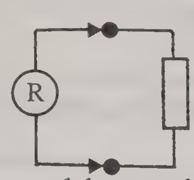
When this voltmeter is placed across low resistance circuits it will not affect their operation, but will appreciately load or shunt high resistance ones.



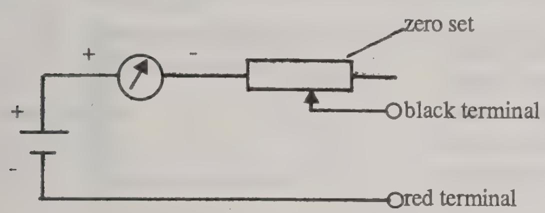
In circuit 'b' the meter will load R2 down effectively to about 83KΩ and upset the original p.d. or voltage drop.

The ohm-meter

Circuit symbol:



The part to be measured is removed from the circuit and the ohm-meter is placed ACROSS the part. The ohm-meter consists of a meter movement and internal battery that deliberately supplies current into the unknown resistance.



The lower the resistance measured, the more current that will flow through the meter movement. The face of the meter is therefore calibrated with 0 ohms at 'full-scale-deflection', (f.s.d.). The meter is adjusted before use by shorting the terminals together and adjusting the 'zero-set' control to obtain a 0Ω (full-scale) reading.

The multimeter

This is a very useful instrument, found in most 'ham' shacks, and allows the measurement of current, voltage, or resistance, each with different ranges and all using the same meter movement. A large rotary multi-contact switch is used to select various combinations of shunt and series resistors.

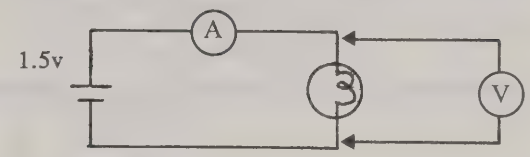
Experiments 1 - 6

Parts required:

- 2x multimeters, one with 10amp current range. (One multimeter would do but makes more work during the experiments). *Note- if planning to buy a multimeter read notes on page 6.3 first.*
- 2x identical torch bulbs, approx. 2.3v each.
- 2x 1.5v size AA red drycells.
- 1x 1.5v size D black drycell.
- 1x 2.2Ω 0.25w resistor
- 2x 2.2kΩ 0.25w resistor
- 1x 2.7kΩ 0.25w resistor
- 1x 3.3kΩ 0.25w resistor
- 2x 560kΩ 0.25w resistor
- 1x 60mm nail
- 1x permanent magnet (from old speaker?)
- 1x switch
- 1 metre insulated 'hook-up' wire
- Assorted metal paper clips

<u>Experiment 1:</u> **The electric circuit.**

a)

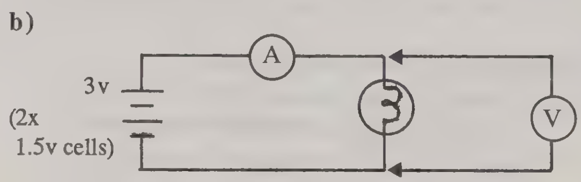


lamp brightness- dull / bright

I = ______ E_{lamp} = ______

Is this a complete circuit? ______

b)

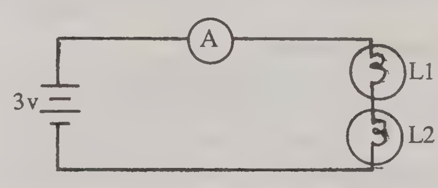


lamp brightness- dull / bright

I = ______ E_{lamp} = ______

How does this differ from a) above?

c)

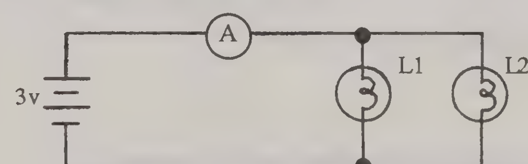


brightness L1- dull / bright
brightness L2- dull / bright

I = ______ E_{L1} = ______ E_{L2} = ______

How does this behave in respect to a voltage divider?

d)



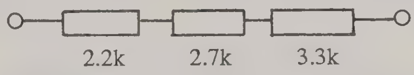
brightness L1- dull / bright
brightness L2- dull / bright

I = ______ E_{L1} = ______ E_{L2} = ______

What has happened to the current drawn from the battery and why?

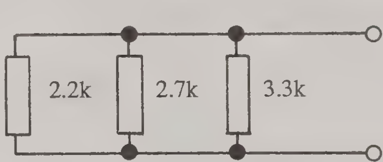
Experiment 2: **Resistors, series & parallel**

a) series-



R_T ohmmeter ______ Calculate R_T _____ Compare.

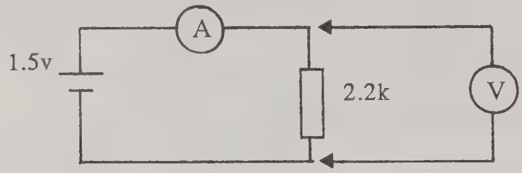
b) parallel-



R_T ohmmeter ______ Calculate R_T _____ Compare.

Experiment 3: **Ohms law and power**

a)



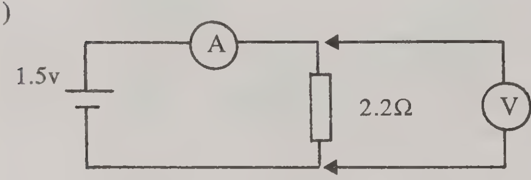
I = ________ E_R = ________

Temperature of resistor- cold / hot (to touch)

Calculate R using meter readings _______ and compare with marked value.

Calculate power in resistor- ________

b)



Caution- *do not leave this circuit connected for more than a few seconds to avoid damage to resistor.*

I = ______ E_R = _______

Temperature of resistor- cold / hot *disconnect circuit*

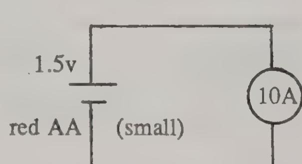
Calculate power in resistor- _______

Experiment 4: **battery internal resistance**

a)

Battery e.m.f. before connecting- _______

Current- _______

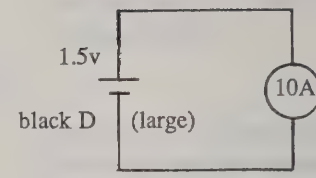


Calculate internal battery resistance using ohms law- _______

b)

Battery e.m.f. before connecting- ______

Current- ______

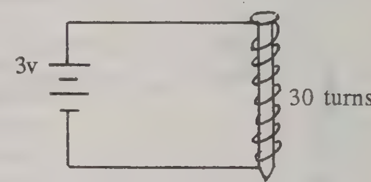


Calculate internal battery R using ohms law- ______ Compare with a).

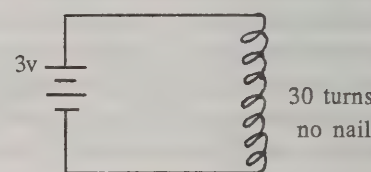
Experiment 5: **Electromagnetism**

a)

using paper clips, check the circuits effectiveness as a magnet.

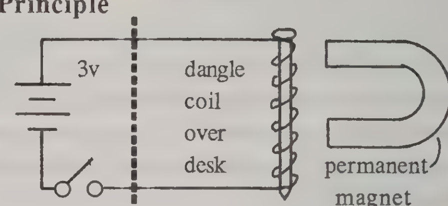


b)



Circuits effectiveness as a magnet?

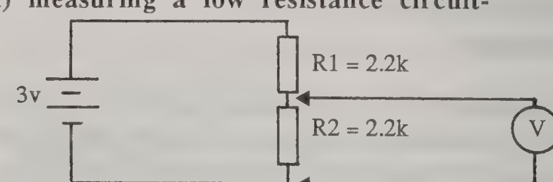
c) Motor Principle



Does the coil move when the switch is opened and closed?

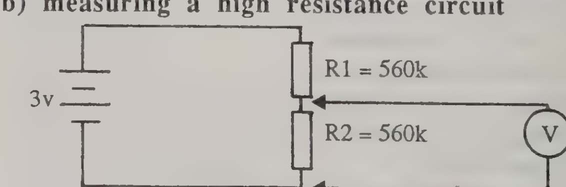
Experiment 6: **Meter sensitivity**

a) measuring a low resistance circuit-



Calculate E_R - _____ Measure E_R - _____ Compare

b) measuring a high resistance circuit



Calculate E_R - _______ Measure E_R - _______

How do they compare and why?

Assignment 4.

1. The moving coil meter may be calibrated in many units, yet really the meter movement operates due to the -

   A. Voltage across the coil in the meter movement.
   B. Current flowing through the coil in the meter movement.
   C. Internal resistance of the coil in the meter movement.
   D. Potential difference between the terminals of the meter movement.

2. Accurate current measurements in a circuit can only be made if the ammeter -

   A. Has a very high damping factor.
   B. Has a very low resistance.
   C. Has a very high internal impedance.
   D. Is operated in a vertical rather than a horizontal plane.

3. When a multimeter is set to the resistance function it -

   A. Measures voltage although the meter is calibrated in ohms.
   B. Measures current although the meter is calibrated in ohms.
   C. Measures ohms directly.
   D. Introduces an error due to the load imposed by the component being measured.

4. A voltmeter performance is described as "2000 ohms-per-volt". This means that the current required to cause full scale deflection of the meter would be :

   A. 0.05 milliamperes.
   B. 0.5 milliamperes.
   C. 1 milliampere.
   D. 2 milliamperes.

5. How much current would be taken from the circuit under test by a voltmeter having a sensitivity of 5000 ohms/volt for the needle to give a full scale deflection?

   A. 0.00002 A.
   B. 2 mA.
   C. 200 μA.
   D. 20 mA.

6. A voltmeter should have a high impedance so that it -

   A. Can directly measure radio frequency voltages.
   B. Indicates close to the true voltage.
   C. Can measure current as well as voltage.
   D. Can measure both AC and DC voltages.

7. Accurate voltage measurements can be made on a circuit of appreciable resistance only if the voltmeter -

   A. Has a high damping factor.
   B. Magnetic circuit has a very high reluctance.
   C. Has a very high resistance.
   D. Has a very low friction bearings.

8. A conductance of one Siemen can be said to be -

   A. One ampere per volt.
   B. One milliampere per volt.
   C. One millivolt per ampere.
   D. One volt per milliampere.

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

LESSON 5

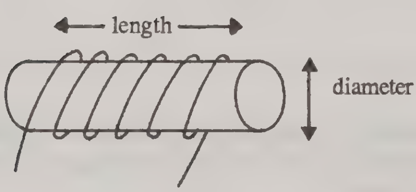
Inductance and capacitance

Inductance

This is the property of a conductor, often in the form of a coil, which allows energy to be stored in an electromagnetic field and is measured in Henries (H).

1H = that inductance which produces an e.m.f. of 1 volt when the current flowing through it is changing at the rate of 1 amp per second.

$$L = \frac{\mu_o \, \mu_r \, A. \, N^2}{\ell} \quad \text{Henries}$$

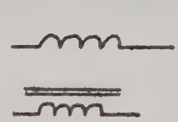


L = Inductance in Henries
μ_o = permeability = $4\pi \times 10^{-7}$
μ_r = relative permeability
A = cross-sectional area of coil
N = number of turns
ℓ = length of coil

INDUCTANCE: measured in Henries (H)
formula symbol L

Inductors

Circuit symbol:



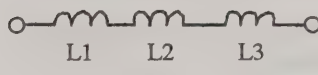
air-cored

iron-cored

These provide inductance and are most commonly in the form of a coil with values from 10μH up to 10H.
By using a core the effective permeability is increased, and so also does the coils inductance. One exception is brass which reduces inductance. The core may be made from iron, iron dust or ferrite. A threaded core can be wound in and out making the inductance variable.

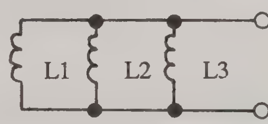
i) Inductors in series:

$$L_T = L1 + L2 + L3$$



ii) Inductors in parallel:

$$\frac{1}{L_T} = \frac{1}{L1} + \frac{1}{L2} + \frac{1}{L3}$$

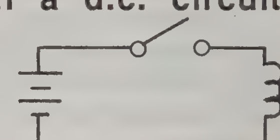


Back e.m.f.

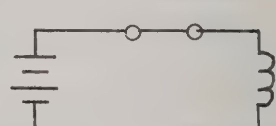
An internally generated, (self induced), emf in a coil, the polarity of which is opposite to the applied voltage. At switch-on, the current flowing through the coil creats a growing magnetic field which then intersects its own windings. Due to the generator principle, a new emf is induced in the same coil. This effect is also known as Lenz's Law and inhibits the immediate build up of current flow. Once the full current is flowing and magnetic field stable the back e.m.f. no longer exists until at switch-off and the collapsing field induces another e.m.f. encouraging the current to continue, often resulting in a spark across the switch contacts.

The inductor in a d.c. circuit

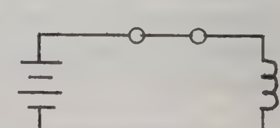
Switch off:
no current flows.



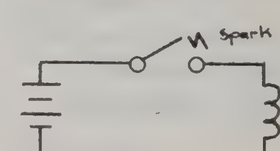
Switch closed:
current increases only slowly due to 'back-emf'.



Switch still closed:
current now stable, energy stored in form of magnetic field.



Switch open: magnetic field collapses, causing another emf, current decreases slowly.

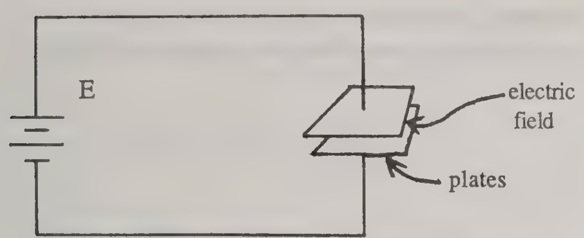


D.c. flows through an inductor but it takes time to respond to an applied e.m.f. or a removed e.m.f.

Capacitance

This is the property of a device which is able to store energy, but this time in an electric field, and is measured in Farads (F).

1F = that capacitance which will hold a charge of 1 coulomb when an e.m.f. of 1 volt is applied.



$$C = \frac{Q}{E}$$

where C = capacitance in Farads
Q = charge in coulombs
E = voltage across plates

Dielectric- The material separating the plates.

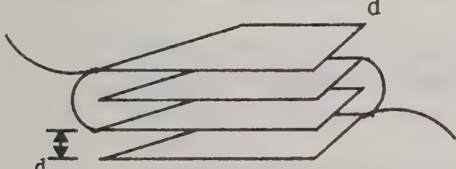
Permittivity (Σo)- the value of capacitance that is possessed by two plates, each 1 metre square, 1 metre apart, in free space.

Relative Permittivity (Σr)- the ratio of increase over Σo if the gap between the plates is filled with a dielectric other than air. Typical values are: air = 1, paper = 2.5, glass = 5, mica = 7.

Breakdown Voltage- that level of high voltage which forces the dielectric in a capacitor to conduct current. This is not a desired condition!

Capacitance Formula:

$$C = \frac{\Sigma o \, \Sigma r \, A \, (N-1)}{d}$$



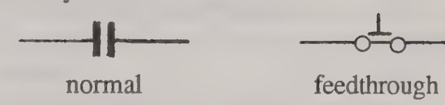
C = Capacitance in Farads
Σo = Permittivity = 8.854 $\times 10^{-12}$
Σr = Relative permittivity
A = area of one plate
N = number of plates
d = distance between plates

<u>CAPACITANCE:</u> measured in Farads (F)
formula symbol C

Capacitors

a) Fixed

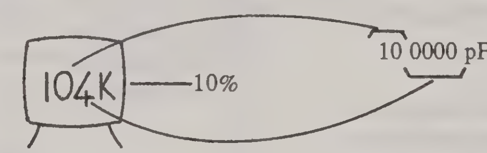
Circuit symbol:



These provide capacitance of set value with sizes ranging from 1pF to 1000μF typically.

Types:

Polyester- (0.001μF - 0.47μF), includes 'greencaps', widely used, polyester & foil. The first two numbers are the significant figures and the third, the number of zeros, the value being in pF. The letter stands for the tolerance: M=20%, K=10%, J=5%.



Electrolytic- (0.47μF - 4,700μF), stores energy in a chemical form enabling large capacitance values for relatively small size. Polarised. Aluminium foil.

Tantalum- (0.1μF - 100μF), tag tantalums, polarised, positive plate tantalum foil, low leakage, small.

Low Loss electrolytic- (0.1 - 220μF), recent substitute for the tag tantalum.

Disc ceramic- (1pF - 0.22μF)

Ceramic Feedthrough-(0.001μF - 0.01μF), mounts on metal chassis.

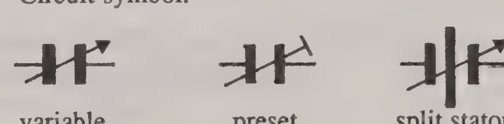
Polystyrene- (33pF - 1000pF), good stability.

Paper- (0.001μF - 10μF), old; superceded by polyester. Paper dielectric.

Different capacitor types lends themselves to particular types of circuits. This will be discussed in lesson 19.

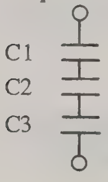
b) Variable

Circuit symbol:



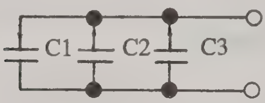
The value of capacitance changes when plate separation is altered.

Capacitors in series:



$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

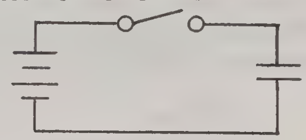
Capacitors in parallel:



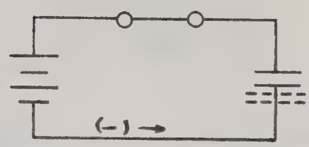
$$C_T = C_1 + C_2 + C_3$$

The capacitor in a d.c. circuit

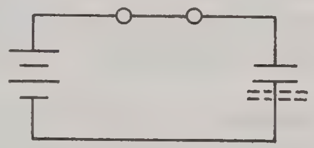
Switch off;
no current flows.



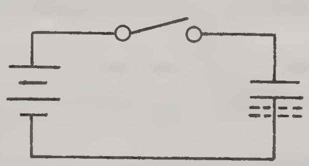
Switch closed;
current briefly flows as electrons gather on lower plate.



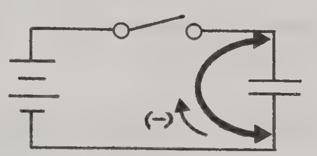
Switch still closed;
no more current flows, capacitor 'charged'.



Switch open;
no current also, capacitor remains charged with a p.d. across its terminals.

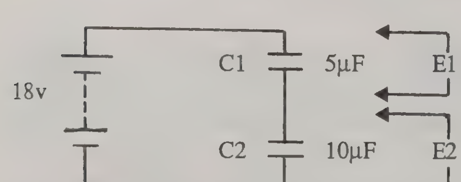


The capacitor is discharged & so able to release its stored energy when provided with external circuit.



D.C. does not literally flow through a capacitor but when an e.m.f. is applied or a discharge path provided, a redistribution of electrons in the circuit will occur, and so current could be said to flow momentarily.

Voltage distribution with series capacitors



$$E_T = E1 + E2$$

The e.m.f. is distributed as potential differences across each capacitor. The value of p.d. will depend upon the capacitors value, the highest voltage being across the smallest capacitance.

Problem: find each p.d. in this circuit:

Formal Method-

a) first find the total effective capacitance of circuit-

$$\frac{1}{C_T} = \frac{1}{C1} + \frac{1}{C2}$$

$$= \frac{1}{5} + \frac{1}{10}$$

$$= \frac{2 + 1}{10}$$

$$= \frac{3}{10}$$

$$\therefore\ C_T = \frac{10}{3}$$

$$= \underline{3.33\ \mu F}$$

b) find total charge in circuit using C_T found above-

$E = \frac{Q}{C}$ therefore $Q = C.E$

$$= 3.33 \times 10^{-6} \times 18$$
$$= \underline{60 \times 10^{-6} \text{ coulombs}}$$

c) finally calculate each p.d. using $E = \frac{Q}{C}$

voltage across C1: $E = \frac{Q}{C} = \frac{60 \times 10^{-6}}{5 \times 10^{-6}}$

$$\therefore\ E1 = \underline{12v}$$

voltage across C2 : $E = \frac{Q}{C} = \frac{60 \times 10^{-6}}{10 \times 10^{-6}}$

$$\therefore\ E2 = \underline{6v}$$

Quick method:

Remember, the higher voltage is across the smaller capacitance, the actual voltage being dependant upon the value of this capacitor in relation to the other one.
In this example $^{5}/_{15}$ of the µF's, (the 5µF capacitor), will have $^{10}/_{15}$'s of the voltage across itself.

$\therefore$ $^{10}/_{15}$ ($^{2}/_{3}$) of voltage will be across 5µF capacitor, and $^{5}/_{15}$ ($^{1}/_{3}$) of voltage will be across 10µF capacitor.

Assignment 5

1. The inductance of a coil varies:

   A. Inversely with the permeability of the core.
   B. Directly with the number of turns of wire.
   C. Directly with the square of the core's permeability.
   D. Directly with the square of the turns of wire.

2. If a brass rod is inserted in an air cored inductor:

   A. The inductance would remain unchanged, but the Q decrease.
   B. The inductance would reduce slightly.
   C. The inductance would remain unchanged, but the Q increase.
   D. The inductance would remain unchanged.

3. A 7 turn inductor has 2 turns removed. What is the approximate relative inductance?

   A. 50%.
   B. 60%.
   C. 70%.
   D. 80%.

4. It is possible to increase the flux density within the core of an iron cored electromagnet by -

   A. Replacing the core with one made of iron having a lower relative permeability.
   B. Replacing the core with one having thinner laminations.
   C. Replacing the coil with one wound with wire having a lower resistivity.
   D. Replacing the coil with one having the same wire and total number of turns, but more turns per layer.

5. For two metal plates, the capacitance between them :

   A. Increases with an increase in plate area.
   B. Decreases with an increase in dielectric constant.
   C. Decreases with an increase in plate area.
   D. Increases with an increase in plate separation.

6. Which of the factors below would <u>NOT</u> influence the capacitance value of a capacitor?

   A. The dielectric constant of the material between the plates.
   B. The distance between the plates.
   C. The area of the plates.
   D. The voltage rating.

7. If 2 capacitors, one of 25µF and the other 50µF are connected in series across a DC supply of 150 volts the voltage that would appear across the 50µF capacitor would be :

   A. 0 volts.
   B. 50 volts.
   C. 75 volts.
   D. 100 volts.

8. Which of the following parameters do not influence the resistance of a conductor?

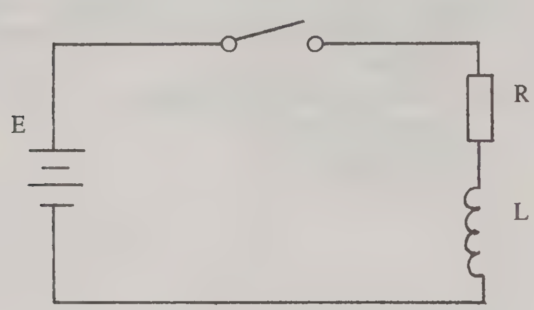
   A. Temperature.
   B. Dielectric constant.
   C. Cross sectional area.
   D. Length.

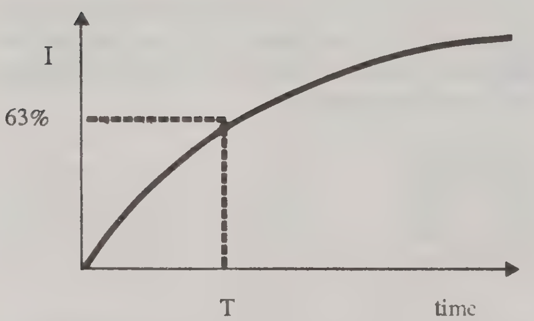
All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Timing circuits

LR time constant

When an inductor and resistor in series are connected to an e.m.f. the time taken for the current to reach 63% of its maximum value is called the LR time constant.





The LR time constant is found:

$$T = \frac{L}{R}$$

where T = time in seconds
L = inductance in Henries
R = resistance in ohms

For example: a coil having an inductance of 5 Henries and a resistance of 10 ohms has a time constant of-

$$T = \frac{L}{R}$$

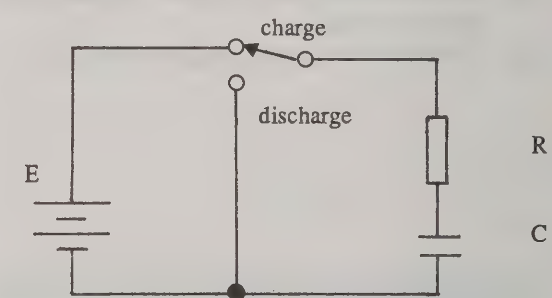
$$= \frac{5}{10}$$

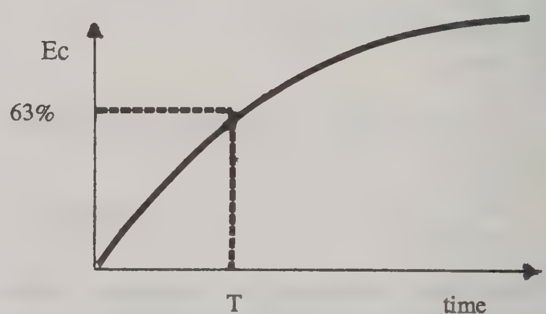
$$= \underline{0.5 \text{ seconds}}$$

CR time constant

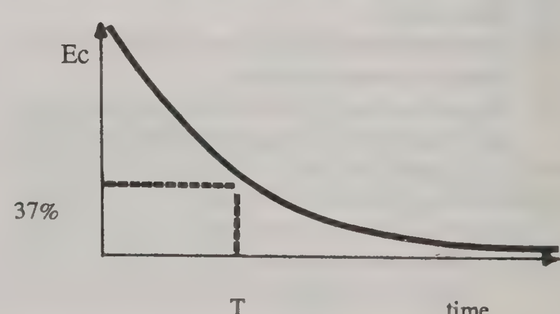
When a capacitor and resistor in series are connected to an e.m.f., the time it takes for the voltage across the capacitor to reach 63% of this applied emf when charging, (or fall to 37% of the maximum voltage on discharge), is called the CR time constant.

This is the most common type with time constants from fractions of a second to several minutes.





Charge



Discharge

The CR time constant is found:

$$T = C.R$$

where
- T = time in seconds
- C = capacitance in Farads
- R = resistance in ohms

<u>Example:</u> the time constant of a 100µF capacitor and 220KΩ resistor is-

$$\begin{aligned} T &= C.R. \\ &= 100 \times 10^{-6} \times 220 \times 10^{3} \\ &= 22{,}000 \times 10^{-3} \\ &= \underline{22 \text{ seconds}} \end{aligned}$$

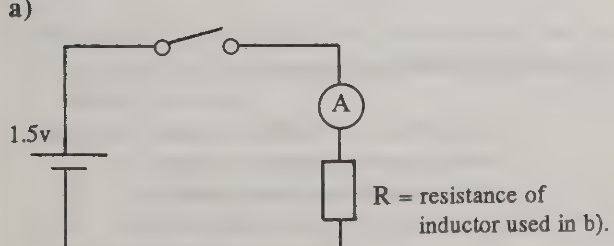
Experiments 7 - 10

Parts required:

- 2x multimeters. (Just one would do if two were not available).
- 1x 1.5v size D black dry cell.
- 1x 9v No. 216 battery.
- 1x 22kΩ 0.25w resistor.
- 1x 47µF 16, (or 25v), electrolytic capacitor
- 2x 470µF 16v electrolytic capacitor
- 1x inductor approx 1H or higher, (otherwise an old large mains transformer).
- 1x resistor, value equal to resistance of inductor.
- 1 metre insulated hook-up wire or leads with alligator clips.

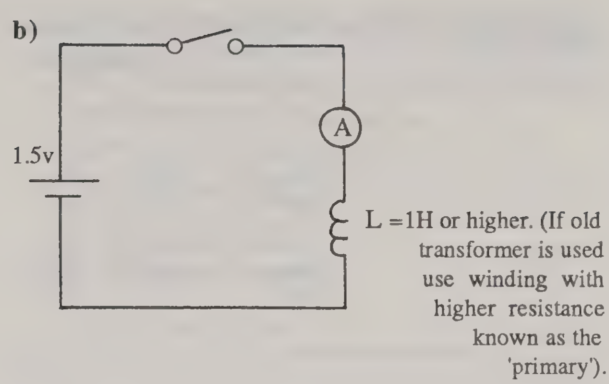
<u>Experiment 7:</u> **The inductor in a d.c. circuit.**

a)



Close switch. Open and close several times, taking a mental note how quickly the needle in the meter rises.

b)

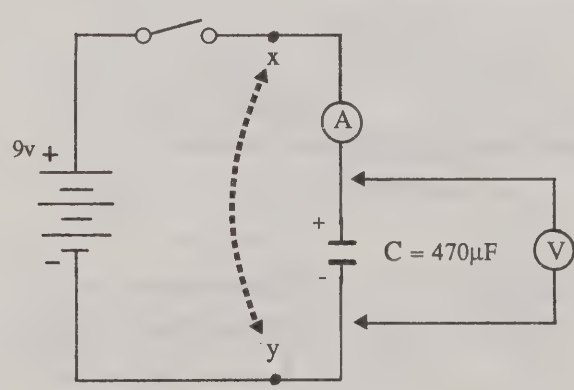


Close switch. Open and close again.

Compared to a), the
needle in the meter is rising: slower / same / faster

How is the inductor in the circuit affecting the initial flow of current?

<u>Experiment 8:</u> **The capacitor in a d.c. circuit.**



Note- please observe capacitor polarity.

Ensure the capacitor is discharged by momentarily shorting its leads together.

Close switch, and observe the ampmeter and voltmeter.

Open the switch and observe the voltmeter.

When did current flow?

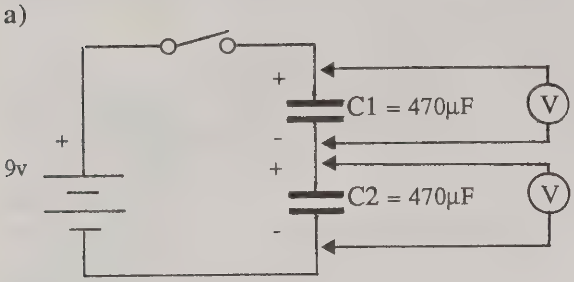
Is the capacitor charged?

Place a wire across points x and y and observe the meters.

What has happened to the capacitor?

Experiment 9: **Voltage distribution with series capacitors.**

a)



Discharge the capacitors. Close switch.

E_{C1} = ______ E_{C2} = ______

Are the two voltages similar? yes / no

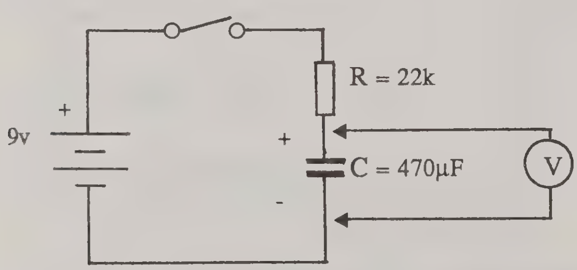
b). Replace C2 with a 47µF capacitor and repeat experiment. (Ensure capacitors have been discharged first).

E_{C1} = ______ E_{C2} = ______

Are the two voltages similar? yes / no

Explain the result.

Experiment 10: **CR Time constant.**



Calculate from the component values the CR time constant- ________sec.

Check capacitor is discharged

Close switch. After one minute E_C = ______ (This will be equal to the applied e.m.f.)

Calculate 63% of this E_C - ________

Open switch and discharge capacitor.

Close switch and time how long it takes to reach this 63% figure- ________sec.

How does this compare with the calculated time?

Projects

Some practical work done at home by building small projects is encouraged so, before we close this lesson, a short discussion on ideas and how to go about this is in order.

The projects need not be anything elaborate but simple straightforward ones will provide valuable practical experience and familiarity with components that will help consolidate some of this mind-boggling theory. One cannot learn to drive a car just from a book but 'hands-on' experience is essential!

A small siren or crystal set when finished may not be your idea of fun, but what a great gift idea when it comes to the children's birthday's that invariably come around. And, whats more, its likely to work which is alot more satisfying than constructing something 'ultra-flash' that then refuses to go.

Kits are the best way to get started as all the components are to hand and you are not hunting around for some obsure part. This is something to watch before embarking on any projects from books or magazines; check first whether you can obtain all the parts.

A few basic tools will be needed:

- Screwdriver set
- diagonal wire cutters approx. 125mm long
- long nose pliers approx 125mm long
- linesman pliers approx 150mm long
- wire strippers
- small-vice, (useful for holding circuit boards when soldering.)
- 25watt soldering iron and solder

An essential instrument is the multimeter. For good all round use the traditional analogue type with the moving-coil meter movement is probably the best type to buy. A newer digital meter would be a good choice later on perhaps when contemplating a second meter.

A few points to look for when buying a multimeter is to ensure the following features:

- a sensitivity of 20,000 (or higher) ohms/volt.
- three or more resistance ranges.
- d.c. current ranges up to 10amps.

Well, go to it and, we will have a look at some of your projects and compare notes later on in another discussion in lesson 19.

Assignment 6.

1. The time constant of a 250 microhenry inductor and a 50 ohm resistance is -

   A. 0.2 microseconds.
   B. 5 microseconds.
   C. 25 microseconds.
   D. 125 microseconds.

2. The time constant of a 100 kilo-ohm resistor and a 1μF capacitor is -

   A. 0.01 seconds.
   B. 0.1 seconds.
   C. 1 second.
   D. 10 seconds.

3. A time constant of 5 seconds is required from an R.C. circuit. If the capacitor has a value of 1000μF the value of the resistor will be -

   A. 200 ohms.
   B. 500 ohms.
   C. 2k ohms.
   D. 5k ohms.

4. The resistance of a conductor depends upon its -

   A. Permeability.
   B. Flux density.
   C. Temperature.
   D. Dielectric constant.

5. In a circuit where a battery is connected directly across a capacitor -

   A. Current slowly increases.
   B. Energy is stored in a magnetic field.
   C. Current does not flow when the capacitor is fully charged.
   D. Electrons traverse the dielectric.

6. Two capacitors, one 2μF and the other 8μF are connected in series across a D.C. supply of 100 volts. The voltage that would appear across the 2μF capacitor would be -

   A. 0 volts.
   B. 20 volts.
   C. 50 volts.
   D. 80 volts.

7. Three inductors, one 8 μH, another 20μH and the third 40μH are all connected in parallel. Assuming there is no mutual inductance, the equivalent inductance of this arrangement is -

   A. 5μH
   B. 13μH
   C. 23μH
   D. 68μH

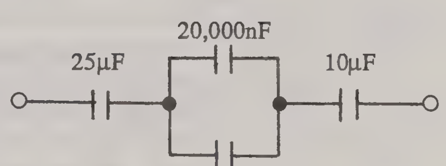


Figure 1

8. The equivalent capacitance of the circuit in figure 1 is -

   A. 6.25μF
   B. 12μF
   C. 47μF
   D. 625μF

Question 2 in this assignment is reproduced from a past examination paper courtesy of RFS.

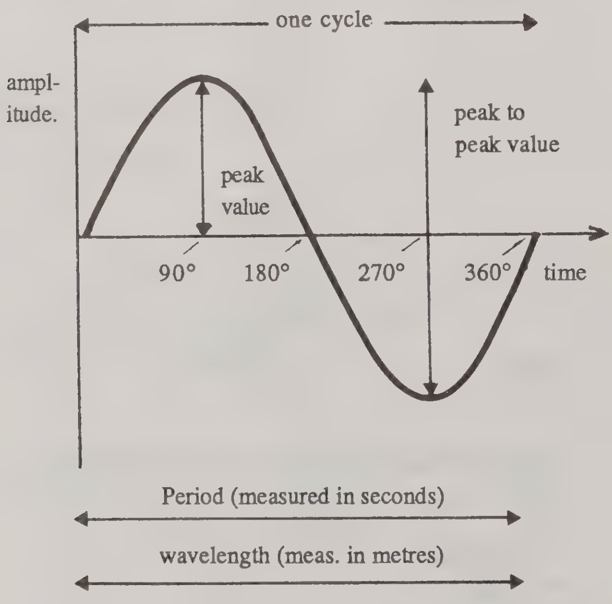
LESSON 7

Alternating current

This is current whose direction of flow changes back and forth due to an e.m.f. that is continuously changing in polarity. A common source of this e.m.f. is the household power point. A.c. is often in the form of a sine wave.

The a.c. waveform

This could represent alternating current or alternating voltage.



Cycle- the complete set of values assumed by the alternating quantity before they are repeated.

Period- the time taken for the quantity to go through one cycle.

Peak value- maximum value assumed by the quantity.

Peak to peak value- maximum value to minimum value.

Instantanous value- the value of the quantity at a given instant.

r.m.s. value- is less than the peak value, and represents the same energy as an equivalently rated d.c. supply. Therefore it can be used in calculations such as ohms law and power ones. It means "root-mean-square" and may be expressed:

$$\text{r.m.s.} = \sqrt{0.5 \ \text{x} \ \text{pk}^2}$$

Frequency (f)- the number of cycles that occur in one second and is measured in Hertz (Hz). Eg. 50 c.p.s. = 50Hz.

Wavelength (λ)- the distance travelled by one cycle of the wave.

Phase- the position or state that the condition is in.

Harmonic- a multiple of some original frequency.

Relationships

1. Frequency

a). As the frequency increases the period will reduce.

$$f = \frac{1}{T}$$

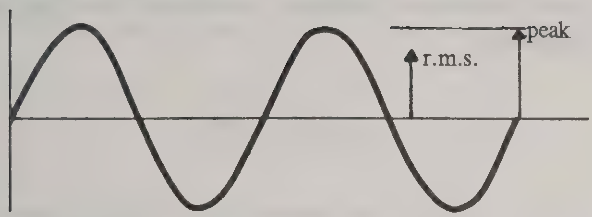
where f = frequency in Hertz
T = time in seconds

b). As the frequency increases the wavelength will become shorter.

$$f = \frac{v}{\lambda}$$

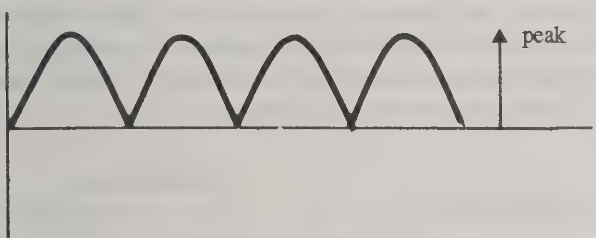
where f = frequency in Hertz
v = velocity of wave (300×10^6 m/sec.)
λ = wavelength in metres

2. Values
a) Sinewave:



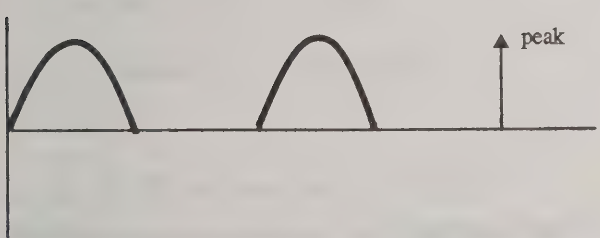
r.m.s. = 0.707 of peak
Peak = 1.414 of r.m.s.
Average = 0

b). Fullwave:



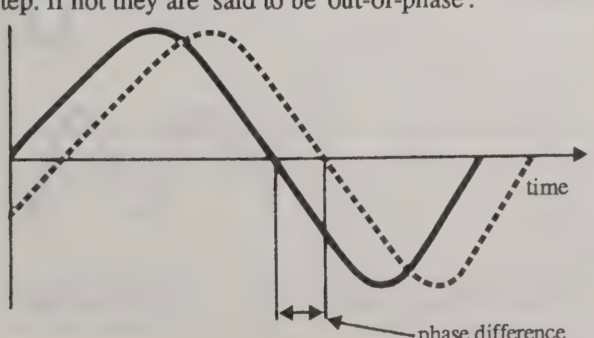
r.m.s. = 0.707 of peak
Peak = 1.414 of r.m.s.
Average = 0.637 of peak

c). Halfwave:



r.m.s. = 0.5 of peak
Peak = 2 x r.m.s.
Average = 0.318 of peak

3. Phase Difference
If there are two sinewaves of the same frequency in the same circuit they may not necessarily be exactly in step. If not they are said to be 'out-of-phase'.



This phase difference may be expressed as:

i) the time difference between them,
ii) a fraction of a period,
iii) more common- in degrees.

Phase Lead: in the diagram the solid wave is said to LEAD the dotted wave.

Phase Lag: the dotted line LAGS the solid wave

Types of a.c.
1. Audio Frequency (A.F.)- those that the human ear will respond which is generally from 30Hz up to 20KHz. (The 'mains' power frequency is 50Hz and can be heard as 'hum' on some equipment).

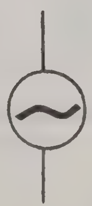
2. Radio Frequency (R.F.)- generally 20KHz and higher. Examples of approximate frequencies are:

navigation beacons- 200KHz
local broadcast stations- 531KHz to 1602KHz
80 metre amateur band- 3.5MHz to 3.9MHz
television ch.1- approx. 47MHz
FM broadcast band 88 to 108 Mhz
2 metre amateur band- 144 to 148MHz
television ch.4- approx. 177MHz
Intellsat communications satellites- 4GHz

The R.F. spectrum is divided up into these classifications:

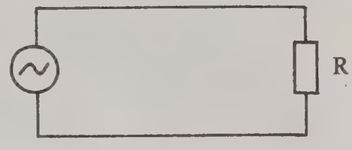
VLF	(very low frequency)	up	to	30KHz
LF	(low frequency)	30KHz	to	300KHz
MF	(medium frequency)	300KHz	to	3MHz
HF	(high frequency)	3MHz	to	30MHz
VHF	(very high frequency)	30MHz	to	300MHz
UHF	(ultra high frequency)	300MHz	to	3GHz
SHF	(super high frequency)	3GHz	to	30GHz
EHF	(extra high frequency)	30GHz	and	above

a.c. source
Circuit symbol:

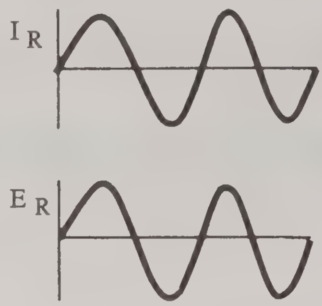


The resistor in an a.c. circuit

Current flows back and forth through R under influence of alternating emf.



Current through resistor is IN phase with voltage across the resistor.



Vector- E & I in phase

Resistance: the resistor will provide the same resistance to A.C. as it does for D.C. Use r.m.s. values for calulations.

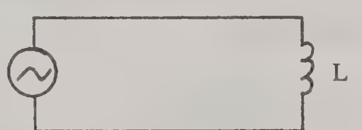
Power- resistor will dissipate power the same as for d.c. Use r.m.s. values for calculations.

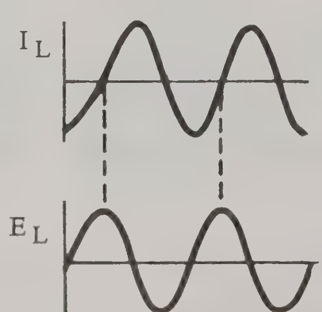
Reactance (X)

The load or opposition within a circuit to the alternating current from either inductors, capacitors, or both, and is measured in ohms (Ω).

The inductor in an a.c. circuit

Current through inductor is OUT of phase with voltage across it due to back emf generated in the inductor.





Current Lags voltage

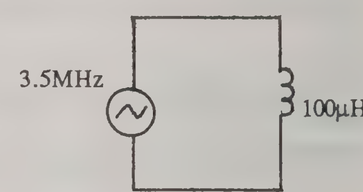
Inductive Reactance (X_L)- This is due to the back e.m.f. opposing change and so reducing the current flow. Inductive reactance increases with higher frequencies.

$$X_L = 2\pi f L$$

where X_L = inductive reactance in ohms
π = pi = approx. 3.14
f = frequency in Hz
L = inductance in Henries

Power- no power is consumed in the ideal inductor because the magnetic field around the inductor is expanding and contracting; storing energy during parts of the cycle and returning in others.

Problem: find X_L



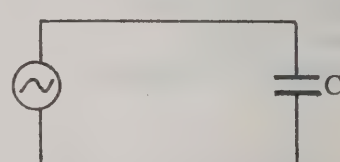
$$X_L = 2\pi f L$$

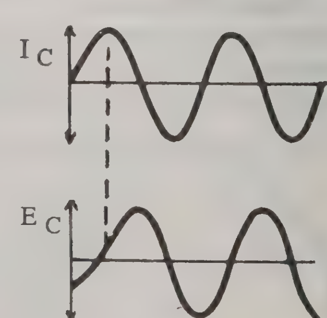
$$= 6.28 \times 3.5 \times 10^6 \times 100 \times 10^{-6}$$

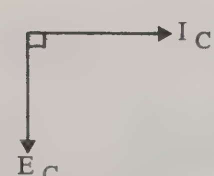
$$= 6.28 \times 350 = \underline{2.2k\Omega}$$

The capacitor in an a.c. circuit

Current in circuit is OUT of phase with voltage across capacitor because a charge across the capacitor is still present, even after the rush of electrons to it has finished.







Current LEADS voltage

Capacitive Reactance (X_C)- this is due to the current flowing only while the capacitor is being charged and discharged. Capacitive reactance decreases with higher frequencies.

$$X_c = \frac{1}{2 \pi f C}$$

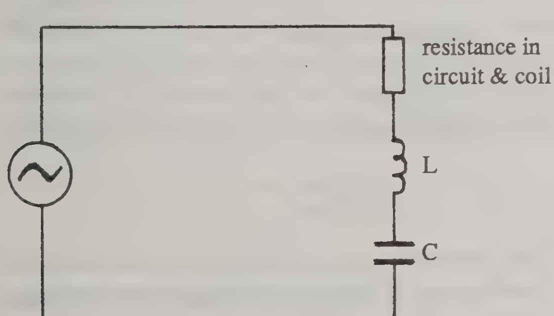
where X_c = capacitive reactance in ohms
π = 3.14
f = frequency in Hz
C = capacitance in Farads

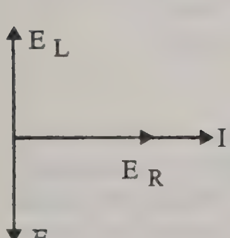
Power: no power is consumed in the pure capacitor but merely stores and returns energy during each cycle.

Civil

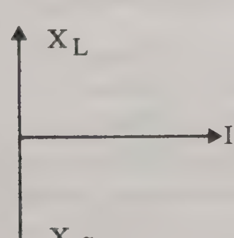
A short-cut way to remember what leads or lags what!

L, C, & R in an a.c. circuit





voltage across L & C 180° apart



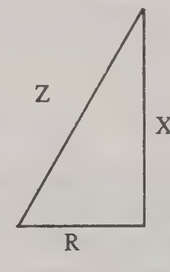
reactances oppose

Impedance (Z)

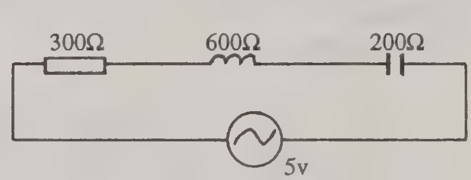
The total opposition to alternating current in a circuit that contains both reactance and resistance and is measured in ohms.

$$Z = \sqrt{R^2 + X^2}$$

where Z = impedance in ohms
R = resistance in ohms
X = overall reactance ($X_L - X_C$) or ($X_C - X_L$)



Problem: find Z, I, E_R, E_L, E_C, P. Draw vectors.



$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{300^2 + 400^2} \qquad = \sqrt{90{,}000 + 160{,}000}$$

$$= \sqrt{250{,}000} \qquad = \underline{500\Omega}$$

$$I = \frac{E}{Z} = \frac{5}{500} = \underline{10mA}$$

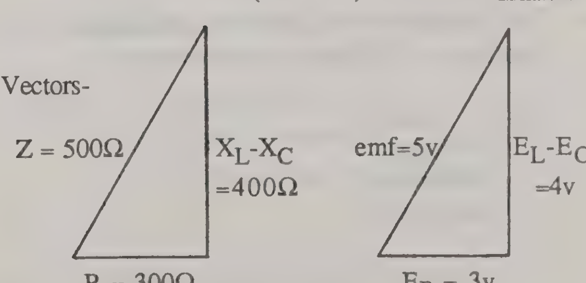
$$E_R = I_R \times R = (10 \times 10^{-3}) \times 300 = \underline{3v}$$

$$E_L = I_L \times X_L = (10 \times 10^{-3}) \times 600 = \underline{6v}$$

$$E_C = I_C \times X_C = (10 \times 10^{-3}) \times 200 = \underline{2v}$$

$$P = I^2 \times R = (10 \times 10^{-3})^2 \times 300 = \underline{30mW}$$

Vectors-



Assignment 7.

1. The third harmonic of 3850 kHz is -

   A. 1925 kHz.
   B. 7700 kHz.
   C. 11550 kHz.
   D. 15400 kHz.

2. A half-wave 50 Hz AC supply and a DC supply are each connected to identical light bulbs and the voltage adjusted until both bulbs have the same brightness. If the DC supply is found to be 6 volts then the AC supply will be 6 volts -

   A. r.m.s.
   B. Peak.
   C. Mean.
   D. Peak-to-Peak.

3. The reactance of a 50μH inductor at a frequency of 7000 kHz is approximately -

   A. 4.5×10^{-7} ohms.
   B. 4.5×10^{-4} ohms.
   C. 2.2×10^{3} ohms.
   D. 2.2×10^{6} ohms.

4. The reactance of an ideal 150 pF capacitor at a frequency of 1500 kHz is approximately -

   A. 7 ohms.
   B. 140 ohms.
   C. 700 ohms.
   D. 1400 ohms.

5. Placing a capacitor in series with a resistor which is carrying an alternating current will -

   A. Reduce the magnitude of the circuit impedance.
   B. Cause the current flowing to lag the applied voltage.
   C. Have no effect on the alternating current flowing.
   D. Reduce the amount of current flowing.

6. With reference to an ideal inductor, which of the following is false?

   A. Back EMF lags the applied voltage by 180 degrees.
   B. Current leads the applied voltage by 90 degrees.
   C. Although current flow is opposed there is no power consumed.
   D. The opposition to current flow is proportional to the frequency of the current.

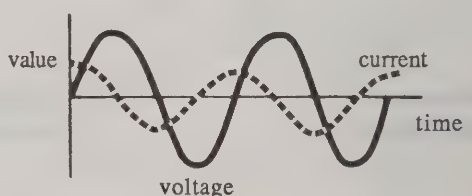


Figure 1.

7. The graph in Figure 1 represents the relationship between applied voltage and resulting current in a particular component. The component has:

   A. Negative resistance
   B. Inductance
   C. Resistance
   D. Capacitance

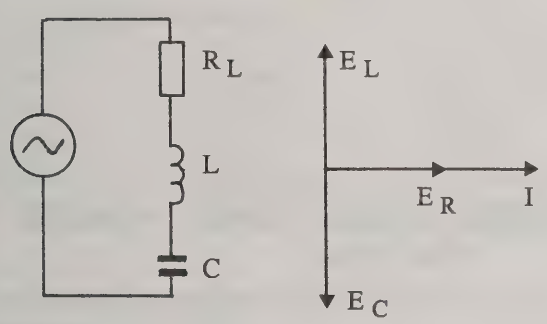
8. The impedance of a series circuit consisting of a resistance of 5 ohms, an inductive reactance of 20 ohms and a capacitive reactance of 8 ohms is approximately-

   A. 3.6 ohms
   B. 13 ohms
   C. 17 ohms
   D. 33 ohms

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Resonance

If in a circuit containing reactances and resistance the applied voltage and resulting current are in phase, the circuit is said to be resonant.



This will only occur if the reactance of the inductor and the reactance of the capacitor are equal. This will also mean that they will have equal voltage drops across themselves too. Because these reactances and their respective voltage drops are 180° out of phase, they will cancel out, leaving only a voltage across the resistance. This will of course be in-phase with the current. (Refer - "The resistor in an a.c. circuit" on page 7.3).

As the frequency applied to this circuit goes up inductive reactance increases, but, capacitive reactance gets smaller, so there will be one frequency where the values will 'cross-over' and be equal. The frequency that this happens at is called the resonant frequency (*fo*).

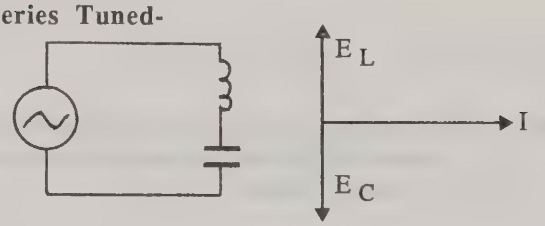
$$fo = \frac{1}{2\pi\sqrt{LC}}$$

where
fo = resonant frequency in Hz
π = 3.14
L = inductance in Henries
C = capacitance in Farads

A circuit like this containing resistance, inductance, and capacitance, is called a 'tuned-circuit'. In practical cases though, the resistor is not a separate component but is mainly just the resistance of the wire in the coil. Tuned circuits have some interesting characteristics as we will see next, and may be considered rather 'magical' at their resonant frequency.

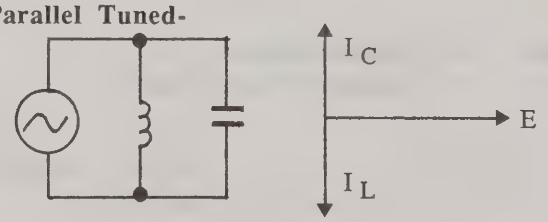
Properties of tuned circuits

Series Tuned-



At resonance-
impedance(Z): minimum
voltage drop: minimum
current flow: maximum

Parallel Tuned-



At resonance-
impedance(Z): maximum
voltage drop: maximum
current flow: minimum

' Q ' factors

These are a measure of a components quality in so far as not to cause any power loss or adversely affect circuit performance.

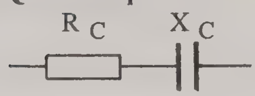
1. Q of Inductors-

$$Q = \frac{X_L}{R_L}$$

where
Q = Quality factor
X_L = inductive reactance
R_L = internal resistance of inductor

R_L should be as low as possible for a high Q.

2. Q of Capacitors-



$$Q = \frac{X_C}{R_C}$$

where X_C = capacitive reactance
R_C = internal resistance of capacitor

3. Q of Tuned Circuits-

$$Q = \frac{X}{R}$$

where X = reactance of coil <u>or</u> capacitor, (not both, remember they are the same at resonance).
R = series resistance

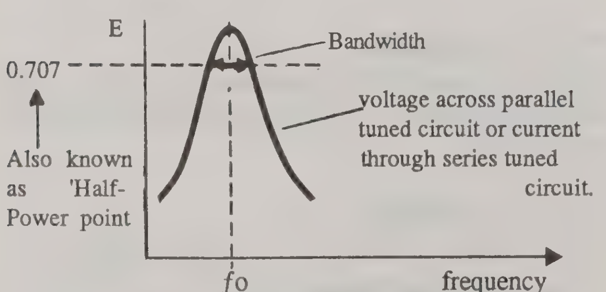
4. Q of Loaded Tuned Circuits- If the tuned circuit has a resistive load across itself in parallel this will affect the ' Q', so:

$$Q = \frac{R}{X}$$

where R = parallel resistance
X = reactance of coil or capacitor

Bandwidth of tuned circuits

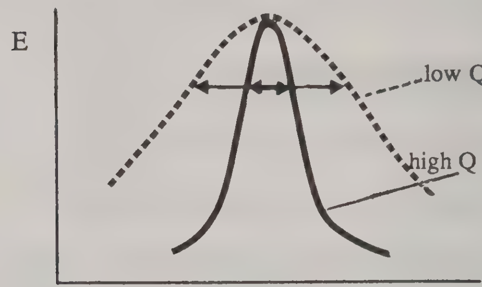
Resonance occurs at only one frequency for any given set of values of inductance and capacitance. But, either side of resonance the effects, although not as predominant, are still there until they 'fall-away'.



$$\text{BANDWIDTH} = \frac{fo}{Q}$$

where fo = resonant frequency
Q = quality factor

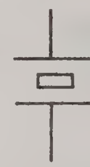
A tuned circuit with a high Q will have a smaller and 'narrower' bandwidth than that of a lower Q:



Response of parallel tuned circuit

Quartz crystal tuned circuits

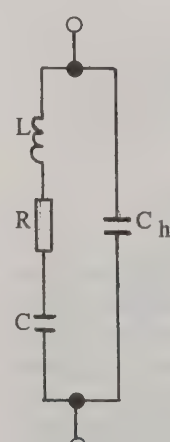
Circuit symbol:

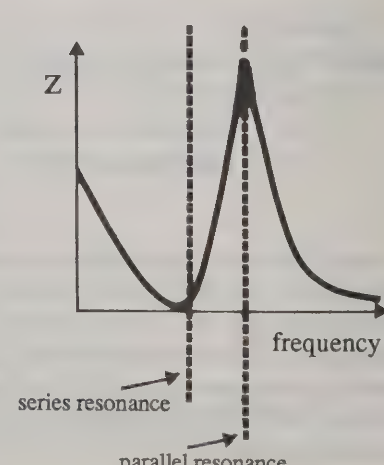


The quartz crystal is essentially a mechanical vibrator that electrically behaves like a tuned circuit.

This is due to a property known as the 'piezoelectric effect'. Some crystalline substances develop an e.m.f. on their surfaces when subject to mechanical stress and, conversely, provide mechanical stress if a voltage is applied.

They are very popular, being easy to use, very stable, and have an extremely high 'Q', often between 5,000 and 50,000. Electrically they are equivalent to both a series and a parallel tuned circuit. Their respective resonance frequencies are slightly apart, the one used being determined by circuit design and the way the crystal is manufactured.

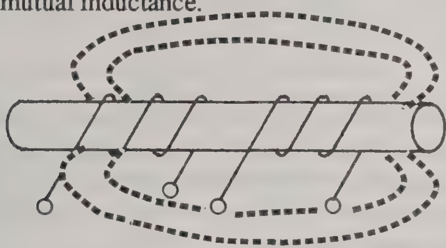




The Transformer:

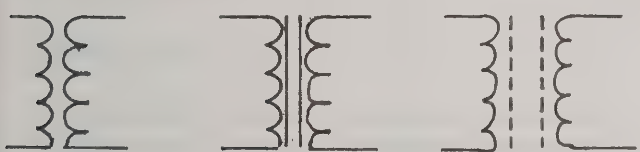
Mutual inductance

When the magnetic field of one coil intersects the windings of another, they are said to be 'coupled' and possess mutual inductance.

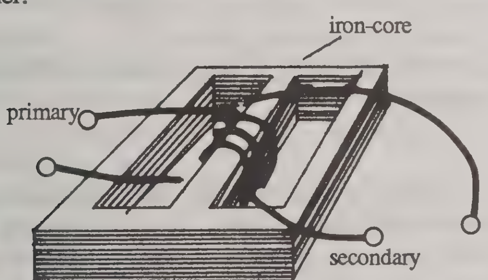


Transformers

Circuit symbols:

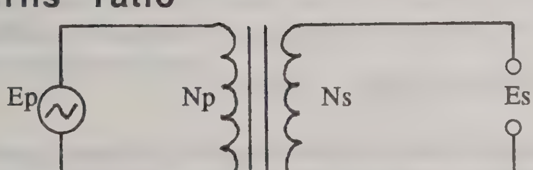


Two or more coils possessing mutual inductance form a transformer.



If one coil, (the primary), is connected to an alternating voltage the changing magnetic field around this coil will 'intersect' the windings of the other, (the secondary), and induce an emf in it.

Turns ratio

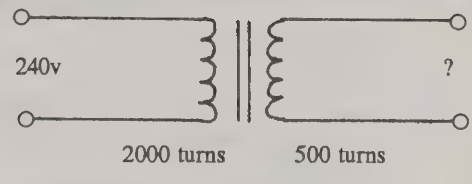


The voltage induced in the secondary is proportional to the ratio of primary to secondary turns.

$$\frac{Np}{Ns} = \frac{Ep}{Es}$$

where Np = number of turns on primary
Ns = number of turns on secondary
Ep = voltage applied to primary
Es = induced secondary emf

Problem: find Es.



$$\frac{Np}{Ns} = \frac{Ep}{Es}$$

$$Np \times Es = Ns \times Ep \quad \text{(cross multiplied)}$$

$$Es = \frac{Ns \times Ep}{Np}$$

$$= \frac{500 \times 240}{2000}$$

$$= \underline{60v}$$

Power ratio

In an ideal transformer- 1 : 1

Although the voltage may be stepped up there won't be any power gain because the current available in the secondary will then be less than that in the primary.

The power delivered to the secondary circuit (Es x Is) therefore, will equal the power in the primary circuit (Ep x Ip), although in practice will actually be less due to losses within the transformer.

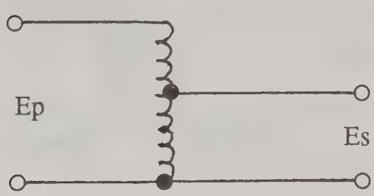
Impedance ratio

Each winding will have its own impedance, will always be in proportion to one another, and related to the turns ratio.

This 'impedance transformation ratio' is equal to the square of the turns ratio.

$$\frac{Zp}{Zs} = \left(\frac{Np}{Ns}\right)^2 \qquad \text{conversely,} \qquad \frac{Np}{Ns} = \sqrt{\frac{Zp}{Zs}}$$

The auto-transformer



This has only one winding with the secondary being common to the primary. The same turns and impedance ratio formulas apply.

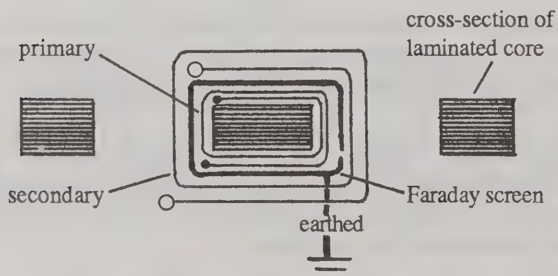
Transformer problems

1. Eddy current loss- currents flow in the core due to flux 'cutting' it. Eliminated by laminating core into thin slices, each one insulated from one another.

2. Hysteresis loss- power lost in magnetising the core back and forth during each cycle and appears as heat. Minimised by using a core of 'soft' material.

3. Copper loss- resistance in windings.

4. Capacitance coupling- primary and secondary appear like two plates of a capacitor and can couple interference clicks and so on from the mains supply. To avoid this a Faraday screen, (electrostatic shield), comprising of an earthed copper, (non-magnetic), sheet is wrapped all but completely around and placed between the primary and secondary windings.

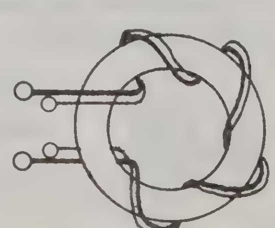


Transformer cores

1. Air- used mainly at v.h.f.

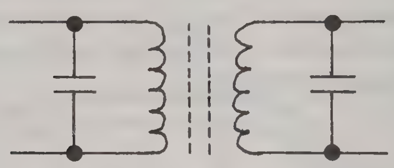
2. Iron- mains and audio frequencies.

3. Ferrite & Powered Iron- r.f. A recent development is the Bifilar toroid transformer where the core is formed into a complete loop giving wideband inductive coupling with minimal capacitive coupling.



Tuned transformers

Circuit symbol:

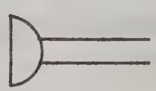


Used at rf where only one group or 'band' of frequencies is wanted to be coupled to the secondary and onto the rest of a circuit. The identical primary and secondary windings form the inductors with each 'side' having the same resonant frequency.

Transducers

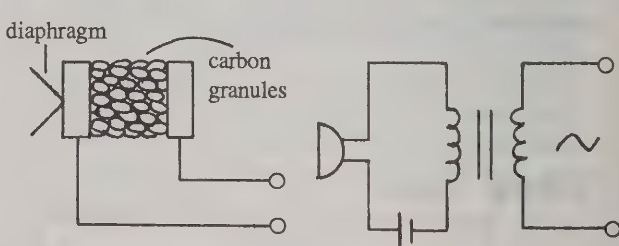
Microphones

Circuit symbol:



Converts the sound of the human voice into electrical alternating current.

1. Carbon- a battery passes current through a capsule filled with carbon granules. As the diaphragm, (attached to the capsule), vibrates, the resistance of the granules varies and causes the battery current to fluctuate in sympathy with the sound. The d.c. portion of the signal is 'removed' by feeding the signal through a transformer.



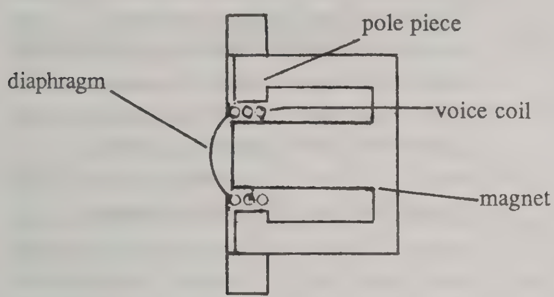
Output level- high Impedance- low

Sensitive, rugged, limited frequency response, granules tend to pack causing distortion and drop in output, affected by temperature and humidity.

2. Crystal and ceramic types- uses the piezoelectric effect where an e.m.f. is developed across a crystal or ceramic 'element' that is attached at one end to the centre of a diaphragm and the other end clamped to the microphone frame. Fragile.

Output level- high Impedance- high

3. Dynamic, moving coil- uses the generator principle, a lightweight coil is attached to a diaphragm and suspended in a circular gap between the poles of a permanent magnet.



Output level- low

Impedance- low

Wide and flat frequency response, low distortion, reliable, the <u>most popular</u> type used by 'hams'.

4. Condenser- the diaphragm and backplate form two plates of a capacitor whose capacitance (C) varies with vibration. A d.c. voltage, supplied by a battery, is applied to these plates which are now 'charged' (fixed Q). As they vibrate a fluctuating voltage (E) will be produced.

$$E = \frac{Q}{C}$$

Impedance- high.

Needs small built in amplifier which can also be designed to convert the output impedance to a low value. Sensitive to wind and rf interference.

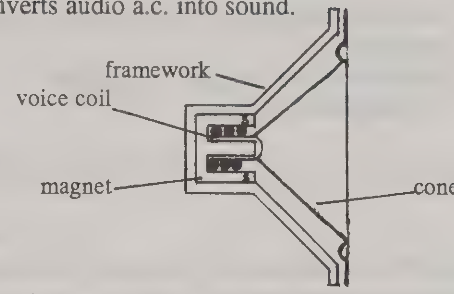
5. Electret- Similar to the condenser except the charge is supplied by an electret material whose electrostatic charge lasts indefinitely and can be made part of the diaphram or backplate. Has battery to drive small impedance converting circuitry that will give a low output impedance.

6. Ribbon, velocity- the diaphragm, being a thin strip of foil suspended between the poles of a permanent magnet, has an e.m.f. induced in it when vibrated. Excellent frequency response and sound quality although rather large and fragile. More for professional 'studio' use!

Loudspeakers

Circuit symbol: 

Converts audio a.c. into sound.



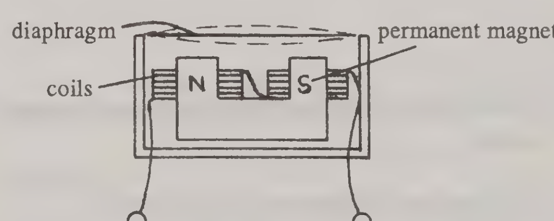
Uses the motor principle whereby audio a.c. currents in the coil set up a magnetic field that interacts with the field from the permanent magnet. This causes the coil, which is fastened to a cone, to vibrate back and forth and produce audible sound. Impedance is low, commonly 4 to 8 ohms .

Headphones

1. Crystal- uses the piezoelectric effect, high impedance, ideal as a small crystal set earpiece.

2. Dynamic- can be like that used in some 'stereo' headphones and are like miniature loudspeakers, low Z.

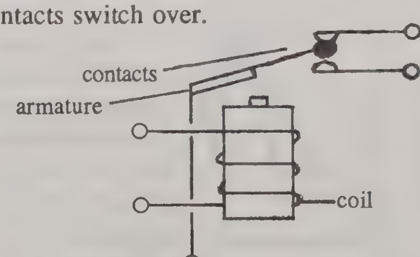
3. Magnetic- the field from two large coils of fine wire, wound around pole pieces of a permanent magnet, influences the field from the magnet and causes the iron diaphragm to vibrate. Mostly high impedance.



Relays

Circuit symbol: 

Current flows through coil, pulls in armature and contacts switch over.



Assignment 8

1. In a series LC circuit tuned to resonance, the reactances of the tuning components:
   A. Are equal to the circuit resistance.
   B. Have a phase angle of 90 degrees between themselves.
   C. Are equal but 180 degrees out of phase.
   D. Are completely in phase.

2. What is the impedance at resonance of a series tuned circuit consisting of a 50µH inductor, a 100pF capacitor and a 50 ohm resistor?

   A. 50 ohms.
   B. 200 ohms
   C. 100 kilohms
   D. 0.5 megohms

3. The "Q" of a series resonant circuit is given by the ratio of-

   A. The inductive to capacitive reactance.
   B. The difference between the inductive and capacitive reactances to the circuit resistance.
   C. The circuit impedance to the circuit resistance.
   D. The voltage across the inductive reactance to that of the generator.

4. The introduction of resistance into a parallel tuned circuit-

   A. Reduces the effective Q of the circuit.
   B. Causes the circuit to tune more sharply.
   C. Increases the resonance circulating current.
   D. Reduces the circuit's bandwidth.

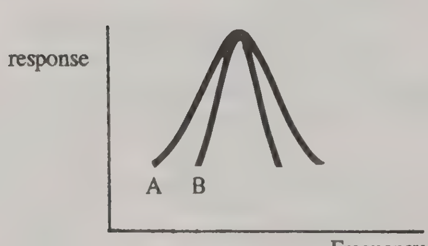


Figure 1

5. The graph in Figure 1 shows curves from 2 resonant circuits A and B. It may be said about these circuits that-

   A. Circuit A is high Q series resonant and Circuit B is low Q series resonant.
   B. Circuit A is low Q series resonant and Circuit B is high Q series resonant
   C. Circuit A is high Q parallel resonant and Circuit B is low Q parallel resonant.
   D. Circuit A is low Q parallel resonant and Circuit B is high Q parallel resonant.

6. Which of the following is true of mutual coupling?

   A. It will not work at less than critical coupling.
   B. It requires a transformer
   C. It can be achieved with capacitors.
   D. It will not work when overcoupled.

7. A transformer is to be used to match a 100 ohm source impedance to a 900 ohm load impedance. The primary to secondary turns ratio required is-

   A. 1 : 81
   B. 1 : 9
   C. 9 : 1
   D. 1 : 3

8. For its operation, the dynamic microphone depends on-

   A. Varying induction.
   B. Magnetic shielding
   C. Varying capacitance.
   D. Varying permittivity

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

LESSON 9

Semiconductors 1

Semiconductors are crystalline substances that are not always good conductors or good insulators but often somewhere between these two states. At low temperatures they are in fact good insulators, yet at room temperature and above, or with exposure to light, the electrons in some of the semiconductor atoms break free and are able to conduct electric current. This is actually opposite to most conductors such as copper where resistance increases with an increase in temperature. Hence, semiconductors are said to have a 'negative' temperature coefficient. Even at room temperature they are not perfect conductors though, and even a large block of about one cubic centimetre has a resistance of one ohm.

The most common semiconductor materials are silicon and germanium. Selenium used to be used in the past.

Doping- the process whereby small quantities of impurities are added to a pure semiconductor to increase its conductivity.

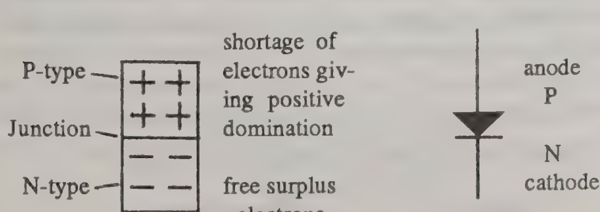
'N'-type semiconductor- that which has been doped with arsenic, antimony or phosphorus. Any of these impurities cause a <u>surplus</u> of electrons within the semiconductor.

'P'-type semiconductor- that which has been doped with aluminium, boron, gallium or indium causing a <u>shortage</u> of electrons, or in effect, 'holes' where they would normally be.

The semiconductor diode

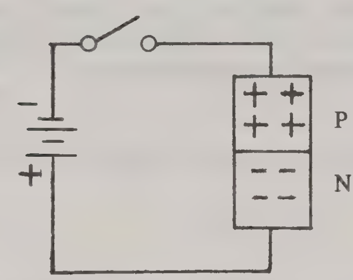
Circuit symbol:

A piece of P-type semiconductor is joined to N-type.



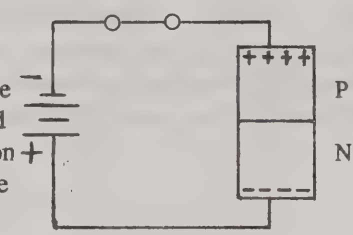
The diode in a d.c. circuit

Switch off:



no current flows.

Switch closed: electrons in N-type material attracted away from junction towards positive battery terminal.

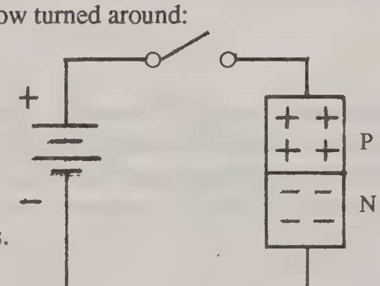


'Holes' (+) in P-type are also attracted away from the junction but towards the battery's negative terminal.

No current flows. The diode is said to be <u>reversed biased</u>.

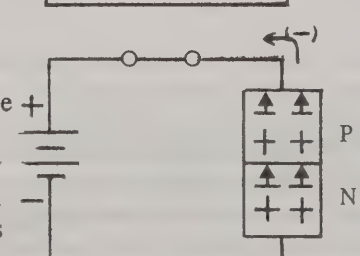
The battery is now turned around:

Switch off,



no current flows.

Switch closed, electrons in N-type material repelled away from battery negative terminal and pushed across the junction into the P-type where they are immediately attracted to the battery's positive terminal.



Current flows. The diode is said to be <u>'forward biased'</u>.

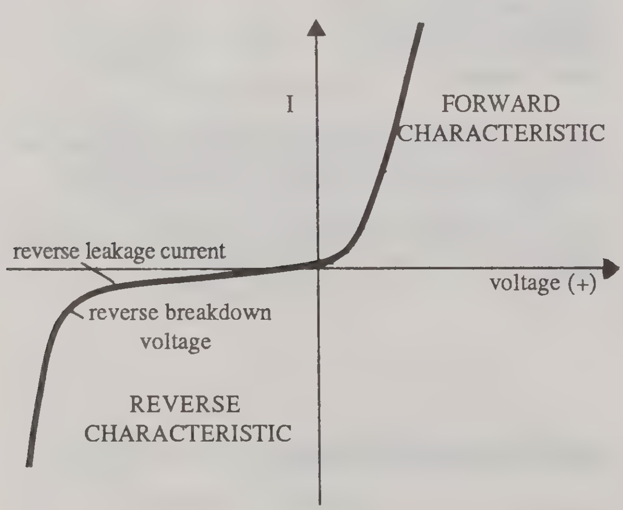
Note- this forward biased condition is met when the P-type semiconductor is connected to the positive (+) terminal of the voltage source, and the N-type is connected to the negative (-) terminal.

Before the diode will start to conduct though, the e.m.f. must be high enough to overcome its natural 'junction barrier potential'. This is generally about 0.7v for silicon diodes and 0.3v for germanium diodes.

Once the diode is conducting, the 'forward voltage drop' across itself will stay virtually the same at 0.7v (silicon), and 0.3v (germanium), irrespective of what of current is flowing through it.

The diode characteristic curve

This is a plot of current flow when the applied voltage is increased from zero, in a forward biased direction, and also shows that for a reversed biased direction.



If the reverse voltage is increased too much it can be seen that the leakage current will rise very quickly and lead to an 'avalanche' breakdown that can destroy the diode unless the current is limited to some safe value.

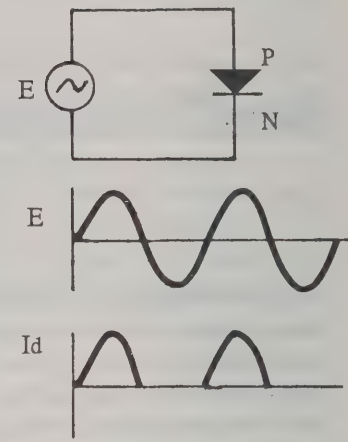
Conventional current

Before the nature of electricity was properly understood current was assumed to flow from positive to negative. Although now known to be incorrect, this is given the name of conventional current and, is still used for the understanding of some electrical and magnetic laws. Also, the arrowhead on semiconductor symbols, such as the diode, points in the direction of conventional current.

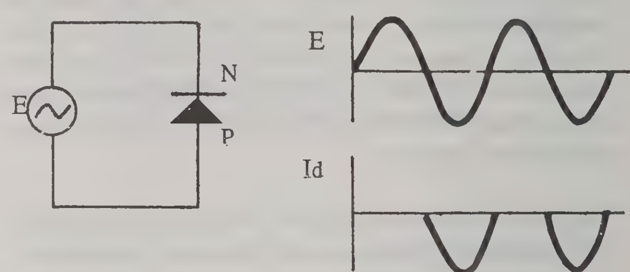
The diode in an a.c. circuit

Current flows only when the diode is forward biased and in this case only when the alternating e.m.f. is positive.

This effect is known as 'rectification'.

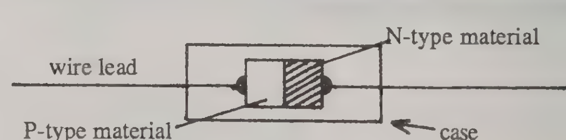


The diode is now reversed:



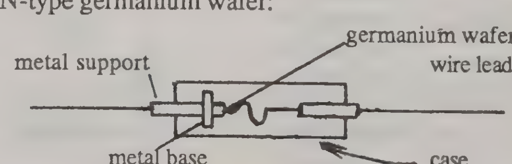
Normal diodes

1. Junction- capable of rectifying high currents and high voltages. High internal capacitance makes it useful only at low frequencies. Mostly silicon.



2. Point Contact- 'cat's whisker', used at r.f. due to low internal capacitance. Can withstand high voltages.

A tiny P-type region is formed under the contact point of a springy tungsten wire which presses against an N-type germanium wafer:



Gold bonded diode

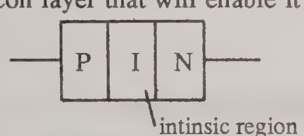
Essentially a point contact diode except the tungsten wire is replaced by a gold one giving higher forward current capabilities and also a lower barrier potential, (at which conduction commences), suiting some small r.f. signal applications.

Hot carrier, Schottky diode

A fairly recent development and consists of a metal to silicon junction giving a very fast response. The junction barrier potential is able to be pre-determined by the manufacturer.
Used in receivers and at r.f. frequencies from v.h.f. to well up into the 'microwave' (1 GHz and higher) region.

PIN diode

Thin P and N-type semiconductor material separated by an intrinsically pure silicon layer that will enable it to withstand high voltages, reduce internal capacitance, and, when forward biased give a very low impedance of less than one ohm.



Used as fast and reliable on/off switches of r.f. frequencies well up into the u.h.f. and 'microwave' region simply by controlling its bias. The PIN diode will conduct r.f. when forward biased, yet appear 'open-circuit' with reverse or no bias.

Zener diode

Circuit symbol: 

This has a characteristic similar to a normal diode but designed to operate with reverse bias on the avalanche breakdown part of the curve. The 'zener' voltage, (just pass the 'knee' of the curve and remaining virtually constant irrespective of what current might be flowing through the diode), can be of a value from 3v to 200v and is determined during manufacture. The zener diode is very useful for providing accurate and stable voltages in circuits and power supplies. More about this in lesson 13.

Variable capacitance diode

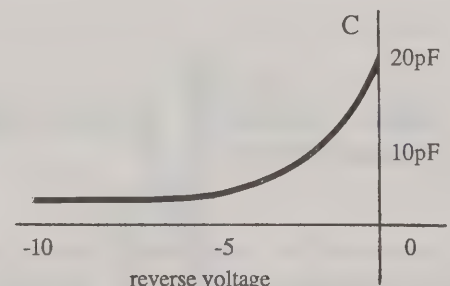
Circuit symbol: 

Varicap, epicap, or Varactor, variable reactance diode: used in tuned circuits where they behave as a variable capacitor, the value of which is changed by varying the reverse bias voltage. They fall into two categories:

i) Abrupt junction- provide the simple capacitance variation.

ii) Graded junction- step recovery, snap: low powered frequency multipliers.

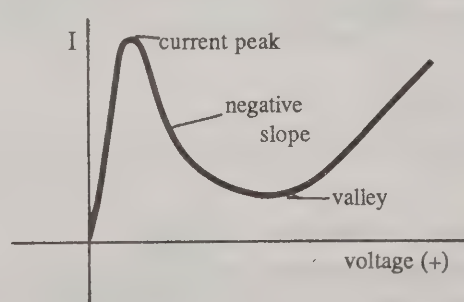
The characteristic curve of a typical variable capacitance diode:



Tunnel diode

Circuit symbol: 

No rectifying properties but has a negative resistance characteristic over part of its curve, where the forward current falls as the forward bias voltage is increasing.



They are manufactured from heavily doped germanium or gallium arsenide and can be used as low noise amplifiers and generators of r.f. frequencies, (oscillators), well up into the microwave region.

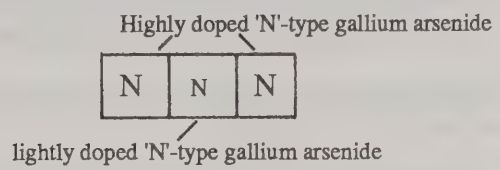
Impatt diode

Used in the reversed bias condition as a low power oscillator of microwave frequencies.

Gunn diode

Circuit symbol: 

Another device with no rectifying properties and a negative resistance characteristic.



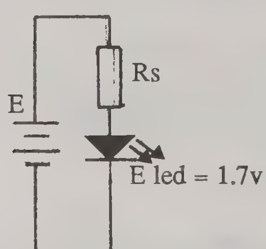
These are an efficient source of medium powered microwave frequencies.

The light emitting diode (LED)

Circuit symbol: 

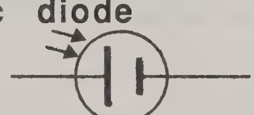
These contain a P-N junction of material which produces luminescence around the junction when forward biased. Widely used as visual indicators instead of the older minature 'filament' dial lamps.

Their current should not exceed about 20mA. The current can be limited by a series resistor whose value can be calculated taking into account a forward voltage drop across the diode of 1.7 v.



$$Rs = \frac{E - 1.7}{I} \text{ (ohms law)}$$

Solar electric diode

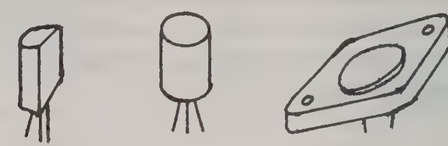
Circuit symbol: 

Solar cell- a large area P-N junction exposed to light causing an increase in holes in the P-type material and an increase in electrons in the N-type material creating an e.m.f. of about 0.5volt. When connected to an external circuit current will flow, approximately 40mA for every square cm of cell material exposed to bright sunlight.

Can be used in series and parallel combinations to give the desired voltage and current capability. Can be used with a 'solar' battery charger.

Bipolar transistors

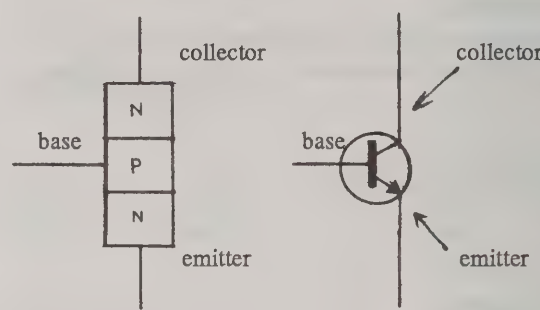
These are three-terminal, semiconductor devices.



1. The NPN Transistor-

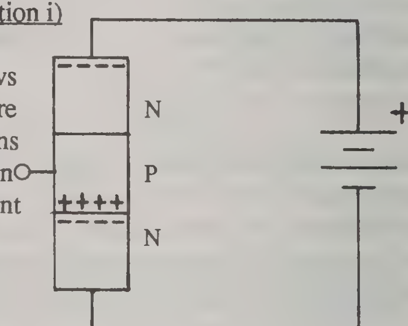
Circuit symbol:

A sandwich of two layers of N-type semiconductor separated by a layer of P-type.

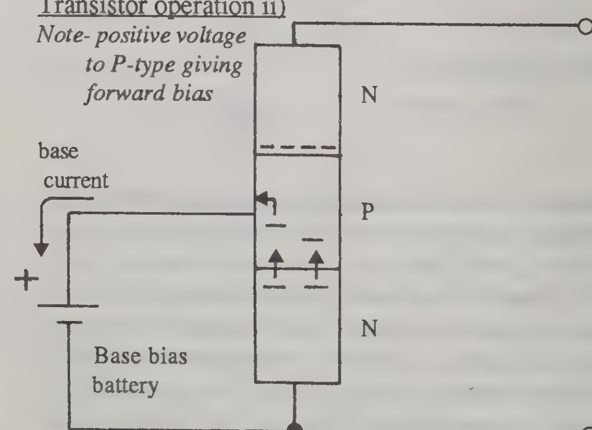


Transistor operation i)

no current flows because there are no free electrons in the base region to enable current flow.

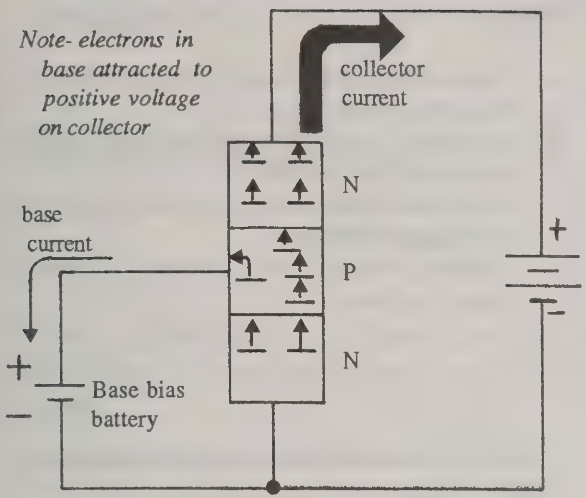


Transistor operation ii)



The base-emitter junction is like a forward biased diode, current flows up through the emitter and out the base.

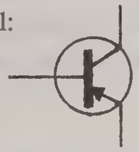
Transistor operation iii)



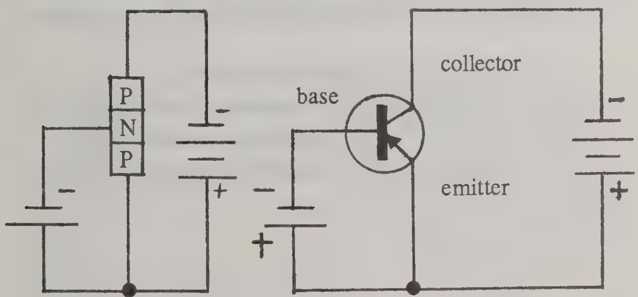
a) electrons are flowing into the base region, (as discussed). While they are here, most of them are attracted by a higher positive voltage on the collector which they can now 'see' and so travel straight on up, through the next P-N junction and, up out the collector. Collector current now flows.

b) If the forward bias on the base is removed no more electrons would flow into the base region and therefore the collector current would have to cease.

2. The PNP Transistor-
Circuit symbol:



Both the base bias and collector voltages are opposite in polarity to that used with the NPN transistor.

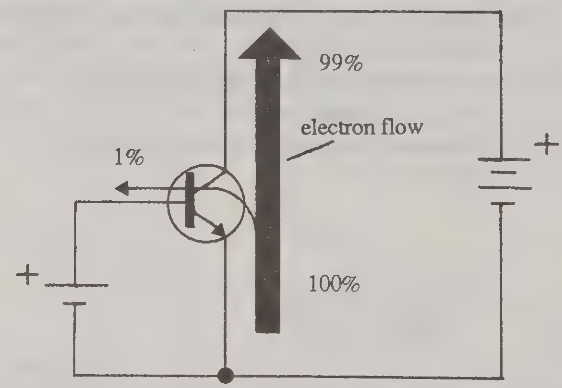


An amplifier

A device whose output is a 'magnified' version of its input and depends on external power sources to function.

A transistor amplifier

Any given transistor connected as shown will have a fixed ratio or percentage of base to collector current. In this example lets say that 1% of the emitter current will flow through the base and 99% will travel straight on up through the collector. In this example then, 99 times the base current will always flow in the collector.



Lets say the base current was just 1µA but somehow we managed to double it to 2µA. This is an increase in base current of 1µA.

Now, the collector current must also double to retain the ratio and be 99 times as much, so if it was 99µA it will automatically double to 198µA, an increase of 99µA.

So a change of 1µA in the base has caused a whopping change of 99µA in the collector.

If it was a signal that caused the base current to change by 1µA the corresponding change in collector current will be a larger one, 99µA in fact. Hence we have amplification!

Assignment 9

1. Semiconductor material has:

   A. High conductivity.
   B. Low resistance at low temperatures.
   C. Greater conductivity than an insulator.
   D. Less conductivity than an insulator.

2. With reference to semiconductors; forward bias applied to a p-n junction :

   A. Changes the semiconductor to a higher resistivity.
   B. Increases the resistance to current flow.
   C. Has a net charge of +5.
   D. Decreases the resistance to current flow.

3. A forward biased diode is one where -

   A. The P-type material is made more negative than the N-type material.
   B. The N-type material is made more positive than the P-type material.
   C. The P-type material is made more positive than the N-type material.
   D. The N-type material is made less negative than the P-type material.

4. A PIN diode has :

   A. An inverted n-type junction.
   B. Its RF resistance controlled by DC current.
   C. Its DC resistance controlled by RF current.
   D. An inverted p-type junction.

5. Over its operating conditions, an ideal zener diode should show -

   A. A constant current through the diode over a wide range of voltages.
   B. A varying current through the diode for a constant applied voltage.
   C. A constant voltage drop over the diode for a wide range of currents.
   D. A varying voltage over the diode for a wide range of currents.

6. A variable capacitance diode used in a tuned circuit operates by varying the -

   A. Forward current through the diode.
   B. Zener breakdown voltage.
   C. Power consumed by the diode.
   D. Reverse bias voltage across the diode.

7. The tunnel diode :

   A. Is intended for use as the rectifier in high current low voltage power supplies.
   B. Is intended for transistor base bias stabilisation.
   C. Exhibits a property known as negative resistance.
   D. Is intended for use as the rectifier in low current high voltage power supplies.

8. The arrowhead drawn on the emitter lead of a bipolar transistor symbol indicates -

   A. The direction of electron flow.
   B. The direction of conventional current flow.
   C. On installation, the lead to connect first.
   D. That the device is a point contact transistor.

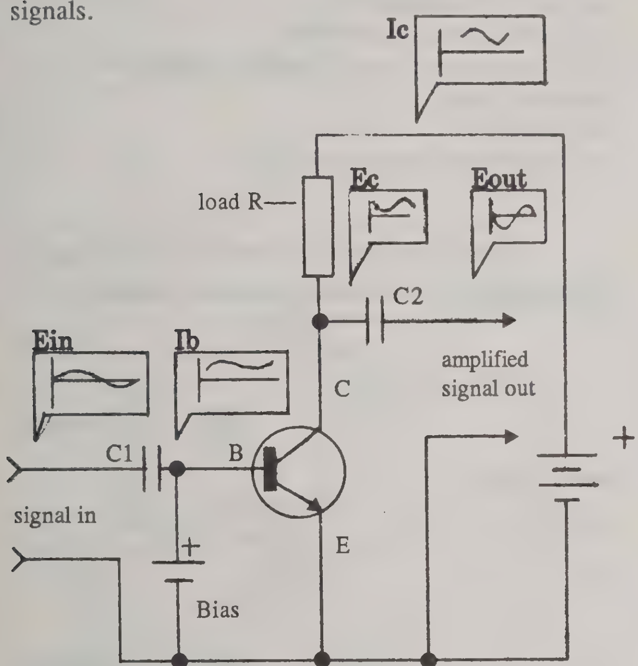
Questions 2 to 8 in this assignment are reproduced from past examination papers courtesy of RFS.

LESSON 10

Semiconductors 2

The common emitter amplifier

The emitter is common to both input and output signals.



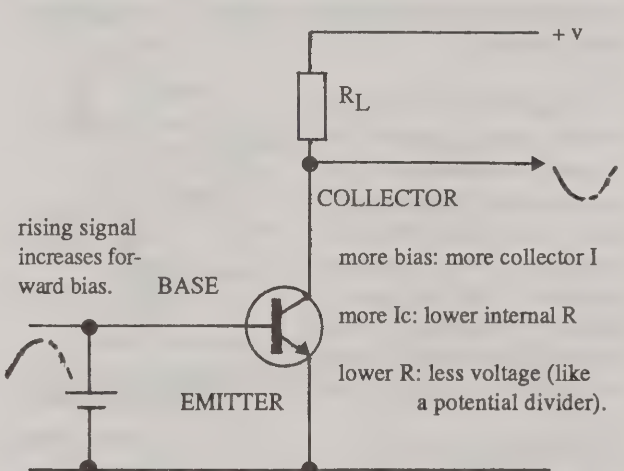
The small alternating signal that is to be amplified is fed to the base of the transistor via C1, and becomes superimposed upon the bias voltage, causing the base current to fluctuate in sympathy with the signal.

The collector current will show a larger variation, (as discussed at the end of the last lesson). This collector current passes through a 'load' resistor which is there to enable a voltage to be 'tapped' off, (across the collector and emitter), like in a voltage divider circuit. Since the collector current is varying by a large amount the voltage taken off across the transistor will also be varying by a sizeable amount.

This output voltage variation is coupled to the next stage via C2 which 'removes' or 'blocks' the d.c. component of the waveform and prevents it from being passed on. Likewise, C1 couples the a.c. signal to the base of the transistor and blocks this amplifiers own d.c. bias from affecting the signal source.

Both C1 and C2 can be referred to as 'coupling' or, 'd.c. blocking' capacitors.

The output voltage will be 180° out of phase with the input voltage. To explain this, lets imagine that the input signal is at a rising part of its cycle causing an increase in collector current. The load resistor is of fixed value, so, to account for this rise in collector current, the internal resistance of the transistor, (between the emitter and collector terminals), must of fallen. The voltage across this now lower emitter-collector resistance, must also fall. But note, these are the same terminals we take the output signal from, in this common emitter amplifier. Therefore the output voltage falls when the input voltage rises.



When the input signal, (within its cycle), starts to fall, the collector current also falls, emitter-collector resistance rises, and so too will the output voltage across the emitter-collector terminals. Therefore, when the complete signal waveform is amplified the output voltage is 180° out of phase with the input voltage.

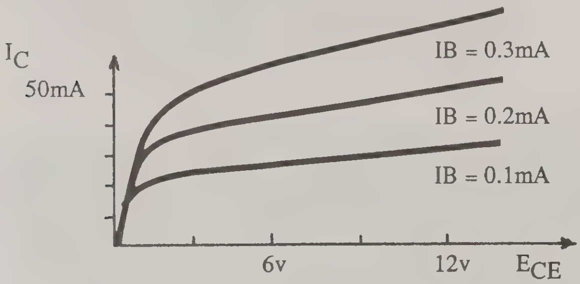
Current Gain (ß or H_{fe})

In the common emitter configuration, the ratio of collector current to base current. (This is the ratio that was mentioned in the last lesson). Typically 50 to 600 and determined in manufacture to meet the specifications for the particular 'type'.

$$\beta = \frac{I_C}{I_B}$$

The transistor characteristic curve

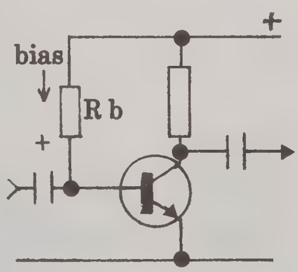
A change in base current (I_B) means a change in collector current (I_C) for a given collector voltage (E_{CE}).



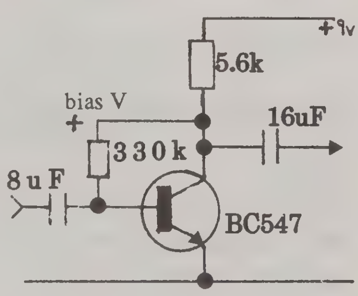
Common emitter biasing

Rather than use a separate bias battery for each stage it is more practical to derive a source of bias from the main supply.

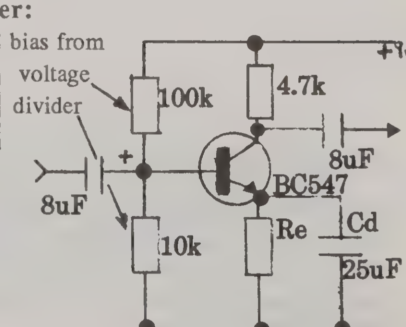
1. Fixed bias- not commonly used, sensitive to varying transistor gains and temperature. If semiconductor temperature rises, its resistance falls, current increases, higher temperature generated, more current, this continues until the transistor destroys itself. Called <u>thermal runaway.</u>



2. Feedback Bias- More stable because if collector current rises, collector voltage falls, and so will the bias that is derived from this point.



3. Voltage Divider: Stable, full gain of transistor obtained. R_E drops voltage across itself to prevent thermal runaway. The charge developed across C_D holds the emitter at a stable potential irrespective of the varying collector current and so maintain the gain of the transistor. C_D is called a 'de-coupling' or signal 'by-pass' capacitor.



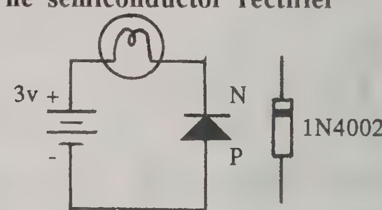
Experiments 11 - 15

Parts required:

2x multimeters
2x 1.5v size AA dry cells connected in series, (3v).
1x 1.5v size D dry cell
1x 9v No. 216 battery
1x 68Ω 0.25w resistor
1x 82Ω 0.25w resistor
2x 180Ω 0.25w resistor
1x 470Ω 0.25w resistor
1x 680Ω 0.25w resistor
1x 1kΩ linear potentiometer
1x torch bulb, approx 2.3v.
1x silicon diode, type 1N4002
1x NPN transistor, type TIP31B or 2N3055
1x box of matches
1x switch
1x set of leads with alligator clips.

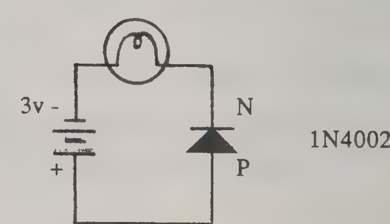
<u>Experiment 11:</u> **The semiconductor rectifier**

a)



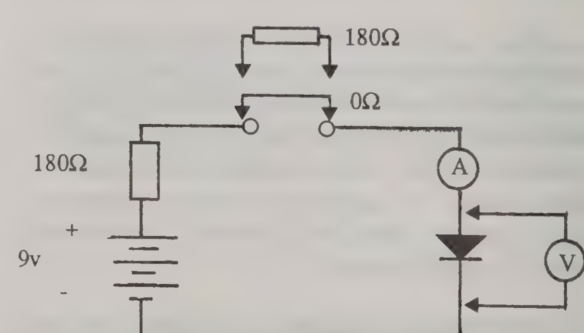
lamp- on/off

b)



lamp- on/off

<u>Experiment 12:</u> **P-N junction voltage drop.**

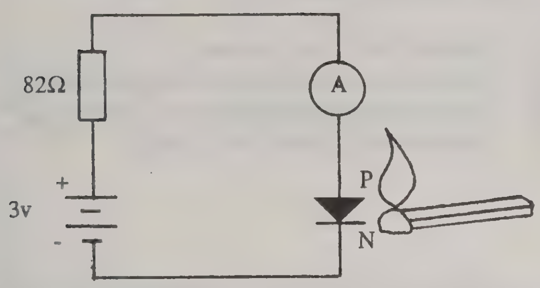


a) 0Ω inserted: E_{diode}= _______ I_{diode}= _______

b) 180Ω inserted: E_{diode}= _______ I_{diode}= _______

Has the forward voltage drop across the diode varied in relation to the different currents flowing through it?

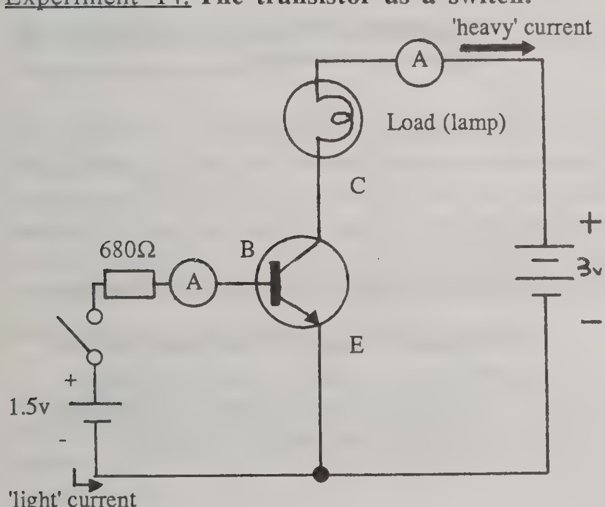
Experiment 13: **Temperature effects.**



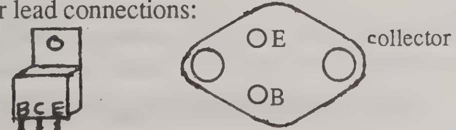
I room temp. = _______ I diode heated = _______

I is: same / lower / higher

Experiment 14: **The transistor as a switch.**



Transistor lead connections:



TIP31B 2N3055

Switch open:

I_B= ______ I_C= ______ lamp- on/off

Switch closed:

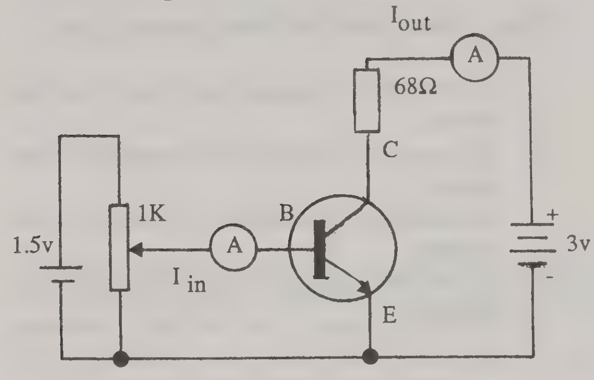
I_B= ______ I_C= ______ lamp- on/off

Is the lamp being controlled by the switch in the base circuit?

What advantage could this circuit have when the lamp, or some other 'heavy' load, is situated some distance away from the switch?

Experiment 15: **The transistor amplifier.**

a) Current gain-



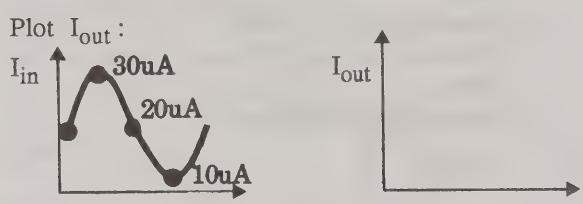
Adjust potentiometer to give I_{in} below. Measure I_{out}.

I_{in} = 30μA I_{out} = _______

I_{in} = 20μA I_{out} = _______

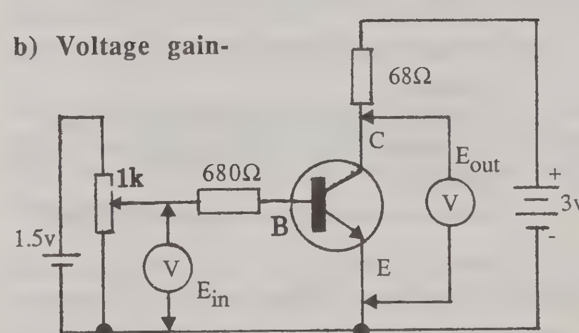
I_{in} = 10μA I_{out} = _______

Plot I_{out} :



Calculate ß - _______

b) Voltage gain-



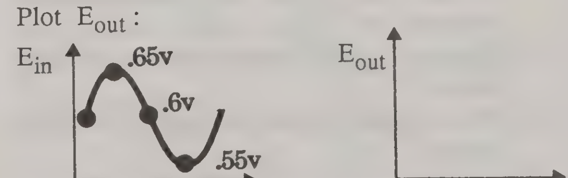
Adjust potentiometer to give E_{in}. Measure E_{out}

E_{in} = 0.55v E_{out} = _______

E_{in} = 0.60v E_{out} = _______

E_{in} = 0.65v E_{out} = _______

Plot E_{out} :



Calculate voltage gain- ______ Phase change= ______

Assignment 10

1. With reference to an NPN transistor amplifier :

   A. Its collector is positive with respect to the emitter.
   B. Its base is negative with respect to the emitter.
   C. Its collector is negative with respect to the emitter.
   D. Its emitter is positive with respect to the collector.

2. The base-emitter circuit in a transistor amplifier circuit has :

   A. Reverse bias for NPN but forward bias for PNP.
   B. Reverse bias at all times.
   C. Reverse bias for PNP but forward bias for NPN.
   D. Forward bias at all times.

3. A silicon NPN transistor used in a common emitter class A amplifier stage would have :

   A. A negative bias voltage applied to its collector.
   B. A negative bias voltage applied to its base.
   C. A positive bias voltage applied to its collector.
   D. A positive bias voltage applied to its base.

4. When a bipolar transistor is connected in the common emitter configuration the transistor's forward current transfer ratio (hfe) can be expressed as -

   A. The emitter current divided by the supply voltage.
   B. The collector voltage divided by the base current.
   C. The base current divided by the collector current.
   D. The collector current divided by the base current.

5. A heat sink is often used with transistors and semiconductor diodes to :

   A. Decrease the forward current.
   B. Prevent excessive junction temperature rise.
   C. Increase the reverse current.
   D. Compensate for excessive doping.

6. When using a multimeter to check a PNP transistor you would expect a low resistance when:

   A. The negative lead is on the base, the positive on the emitter.
   B. The negative lead is on the collector, the positive on the emitter.
   C. The positive lead is on the base, the negative on the emitter.
   D. The positive lead is on the collector, the negative on the emitter.

7. In a diode, the forward current decreases when :

   A. The anode voltage is made more positive.
   B. The anode voltage is made less positive.
   C. The cathode voltage is made more negative.
   D. The junction temperature increases.

8. A light emitting diode will glow when :

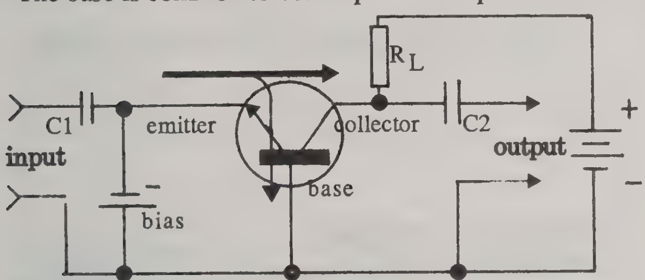
   A. It is reverse biased.
   B. Forward current reaches 200mA.
   C. It is forward biased.
   D. The cathode is positive with respect to the anode.

Question 4 in this assignment is reproduced from a past examination paper courtesy of RFS.

Semiconductors 3

The common base amplifier

The base is common to both input and output circuits.



The base-emitter junction of the transistor is forward biased by the bias battery.

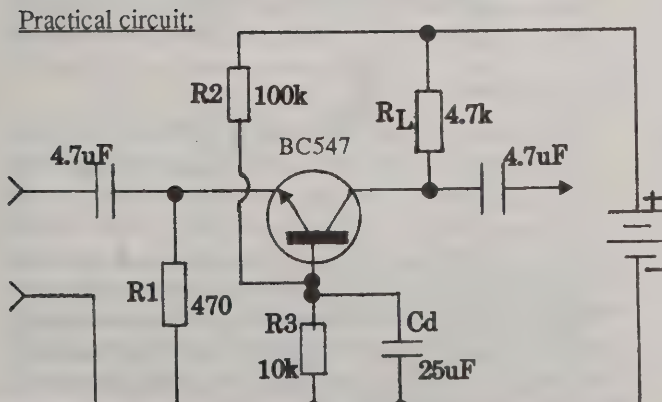
The signal, fed to the emitter, is superimposed on the bias voltage, causing the emitter current to rise up and down with the signal. Now, most of this current flows straight through and out the collector, so the collector current will vary by the same amount. There is no current gain, but there is a voltage gain by using R_L and taking the output between collector and base.

The input impedance is low, (large current flowing in input circuit), and the output impedance is high, (no current flows from base to collector). The output voltage will be in phase.

Current Gain (Alpha α)- in the common base configuration, the ratio of the collector current to the emitter current, and is always less than 1.

$$\alpha = \frac{I_c}{I_E}$$

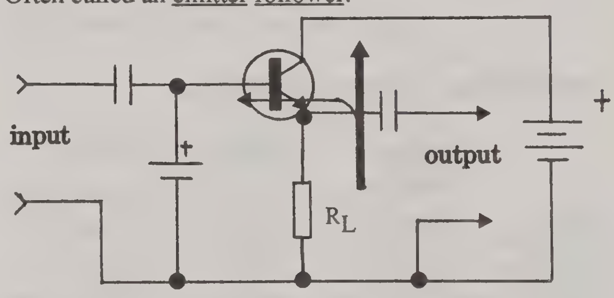
Practical circuit:



The forward bias on the base is derived from the voltage divider R2 and R3, which sets it at some positive potential. The main d.c. current flow is through R1, into the emitter where the signal is superimposed onto it, and out the collector and up through R_L.

The common collector amplifier

Often called an emitter follower.



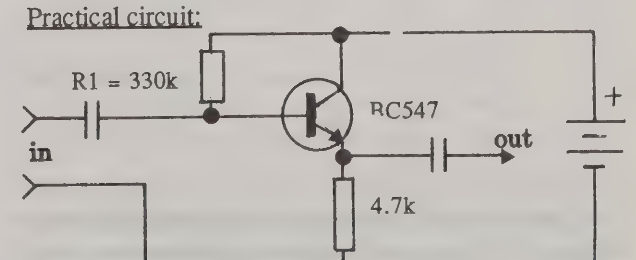
Similar looking to the common emitter circuit, (in the last lesson), but the output is taken across the load resistor which is now connected in the emitter lead.

The signal is applied to the forward biased base, causing the usual large variation in emitter - collector current. Current gain is therefore high, but the voltage gain is less than unity.

Input impedance is high, output impedance is low, (dictated by R_L), so is useful as an impedance matching device, like that required by the electret microphone.

Because the output voltage is across R_L and rises and falls with the emitter current and input signal, there is no phase difference between input and output voltages.

Practical circuit:



Forward bias is obtained by R1

Cut-off frequency

The current amplification of the transistor falls off as frequency is increased. The cut-off frequency is that at which the current gain of the stage falls to 0.707 of its 1KHz value.

The power amplifier

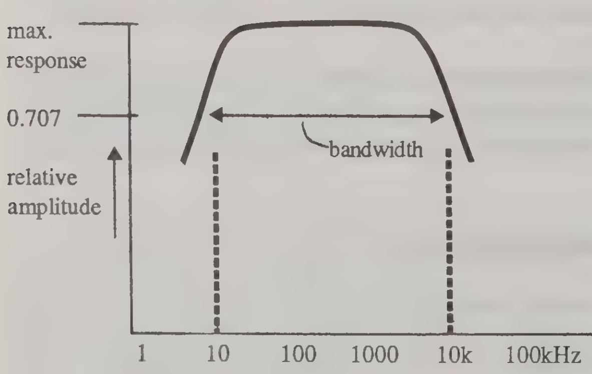
That final stage or stages that supply the amplified signal to its load such as a speaker.

Higher currents and sometimes higher voltages are required to drive such a load, so special transistors capable of handling these must be used. The 'power' transistor is designed to secure onto a metal chassis so as to act as a 'heat-sink', dissipating any heat generated.

Amplifier comparisons

	COMMON EMITTER	COMMON BASE	COMMON COLLECTOR
I GAIN	high	nearly 1	high
E GAIN	high	high	nearly 1
INPUT Z	medium	low	high
OUTPUT Z	medium	high	low
POWER GAIN	high	medium	low
CUT-OFF FRQ	low	high	depends RL
PHASE CH.	180°	none	none

Amplifier frequency response



The bandwidth of an amplifier, or its overall frequency response, is that range of frequencies between lower and upper points where the amplifier gain falls to half power, or 0.707v.

Negative feedback

A portion of the amplified signal is fed back to the input, 180° 'out-of-phase'. Used in amplifiers to increase their frequency response, improve stability, and reduce distortion and noise within feedback stages.

The gain-bandwidth product

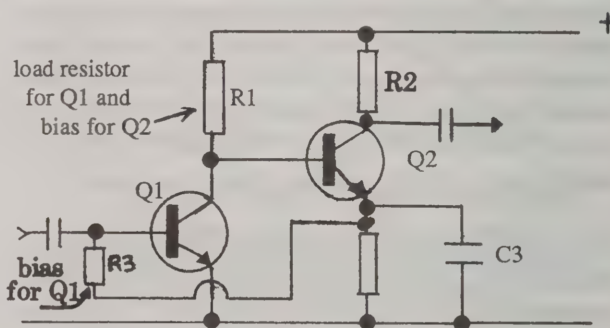
For a given stage:

GAIN X BANDWIDTH = CONSTANT FACTOR

Coupling stages

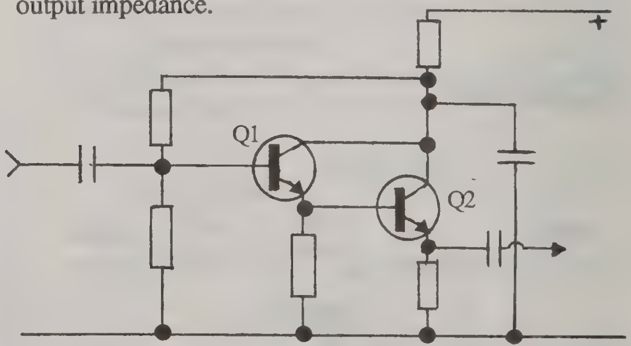
RC Coupled- most common, uses coupling capacitor, used in all previous amplifier circuits.

Direct Coupled- improves frequency response.



C3 may be removed which will allow a negative feedback path via bias resistor R3 and onto the base of Q1 giving an even wider bandwidth. The gain of course will be reduced.

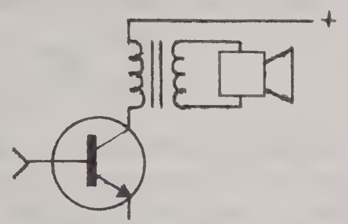
Darlington pair- a type of direct coupling that gives very high gain, a high input impedance, and a low output impedance.



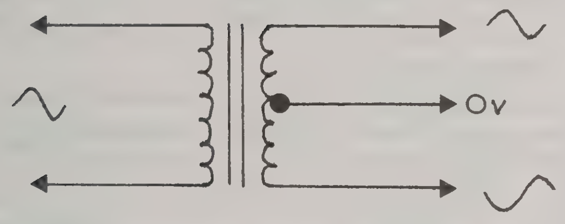
It consists of two emitter follower stages with the emitter current of Q1 flowing through the base-emitter junction of Q2 giving an extremely high current gain. This will be equal to the two individual transistor current gains muliplied together.

Transformer Coupled- to match different impedances of stages, to couple a load, to be a phase-splitter, (splits into two identical 180° out-of-phase waveforms).

i)

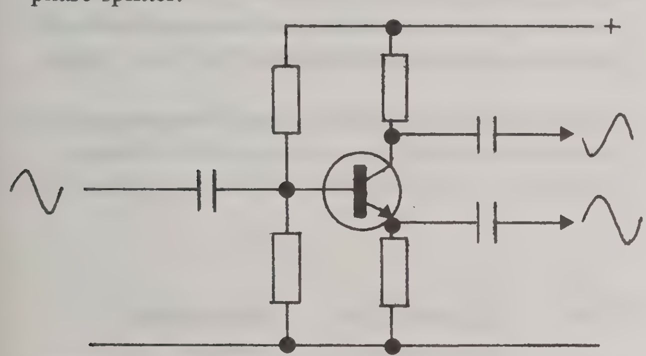


ii)



Transistorised 'phase-splitter'

Phase inverter- this will do the same as the transformer phase-splitter.



Behaves as both a common emitter and emitter follower giving two identical outputs, 180° out of phase.

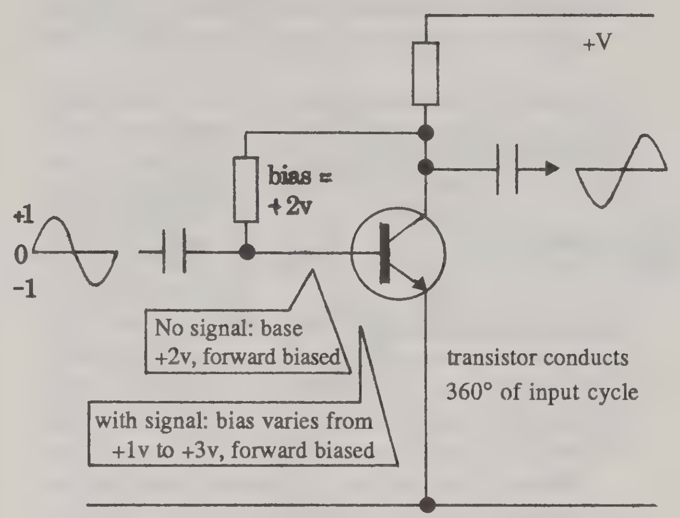
Operating conditions

In all the circuits discussed thus far, the value of bias has been selected so as to enable the base-emitter junction to remain forward biased throughout the whole of the input signal's cycle. This allows the collector current to remain flowing, (varying up and down under the signals influence of course), and is given the name of 'class-A' bias.

A low value of bias might cause part of the cycle to cancel out the bias. This will turn the transistor 'off' for that portion of the cycle. (No forward bias, no base current, no collector current). The signal would be 'distorted' but sometimes this is wanted, such as in transmitters where it would produce harmonics containing a desired frequency, or alternatively to enable higher efficiency, due to less collector current. These special operating conditions of bias are also given names, the most common being 'class B' and 'class C'.

Class A operation

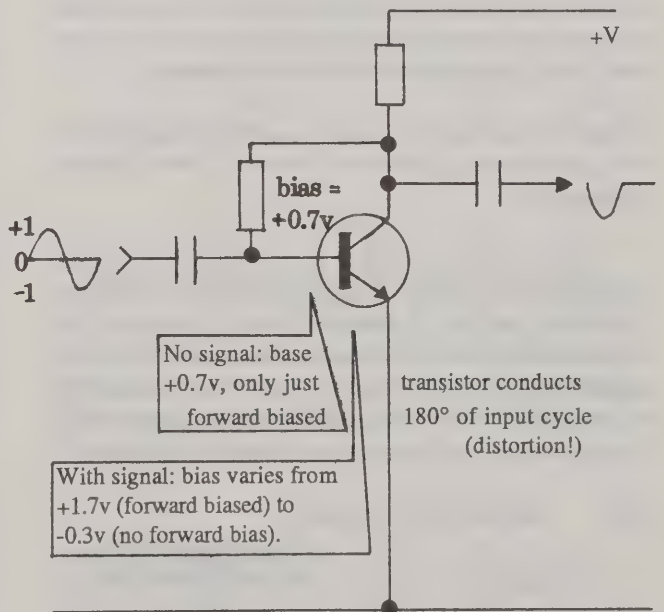
The bias in the stage is such as to allow collector current to flow for the whole (360°) of the input cycle.



All circuits up to now have been class A.

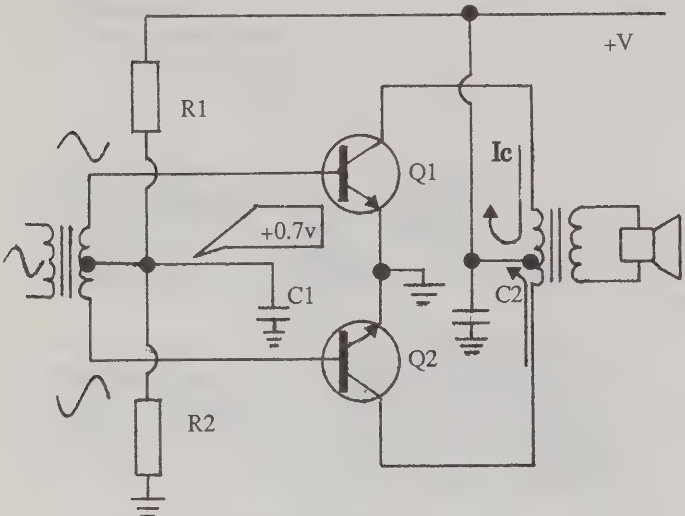
Class B operation

The collector current flows for only half (180°) of the input cycle.



The transistor's base-emitter junction will be only just forward biased at approximately +0.7 volts, (which is its junction barrier potential). Therefore during all of the negative portions of the signal the transistor will 'cut-off'.

To use in practice, and amplify a complete waveform without distortion, two transistors must be used, conducting half the waveform each. This circuit arrangement is called "push-pull".



R1 and R2 form a voltage divider to set the bias at 0.7v which is supplied to both transistor base terminals via the input transformer's secondary winding.

The signal is applied to this transformer, split into two waveforms, 180° out of phase by the centre-tapped secondary, and each fed to a transistor.

Q1 will conduct and amplify the first half of the cycle, (positive going portion on Q1 base), and Q2 will conduct and amplify the second half of the cycle, (positive portion now on Q2 base).

The two amplified halves are recombined in a second centre-tapped transformer and couples the signal, (and 'matches' the impedance of this amplifier stage), to the load. In this example the load is a loudspeaker.

C1 and C2 are audio by-pass capacitors that hold the two centre-tap potentials steady from signal fluctuations.

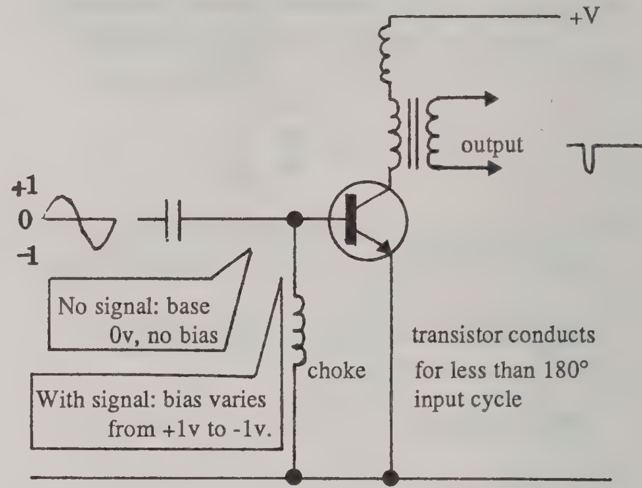
This circuit is typical of that used for power amplifiers, (including that for r.f. transmitter use), because of its high 65% efficiency, (collector current flows only under signal conditions). The amount of collector current will be proportional to the amplitude of the input signal or 'volume' level. (Class A is less than 50% efficient)

Note- Efficiency % of a stage $= \dfrac{100 \text{ x signal output power}}{\text{d.c. power into stage}}$

Two more classes of 'linear' (no distortion) r.f. power amplifiers are classes AB1 and AB2. Two transistors may again be used in push-pull, although in some circumstances only one is used. Bias is set at a level between that for class A and class B. The efficiency obtained falls between these two classes.

Class C operation

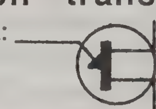
The collector current flows for less than 180° of the input cycle and resembles a short 'pulse'.



No separate bias supply is provided. The base-emitter junction will only be forward biased when the signal exceeds its junction barrier potential, and this will only be for a short portion of the input cycle. The choke, (inductor), provides a path for the bias current during the forward biased conditions, but not affect the r.f. signal.

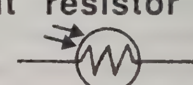
Used at r.f. frequencies and mostly in transmitters. Not a linear amplifier but has a very high 80% efficiency.

The unijunction transistor

Circuit symbol: 

Used in oscillators. More about these in lesson 14.

Light dependent resistor (LDR)

Circuit symbol: 

Very high resistance (10MΩ) in low or no light conditions, and low resistance (200Ω) in bright light.

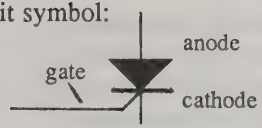
Thermister

Circuit symbol: 

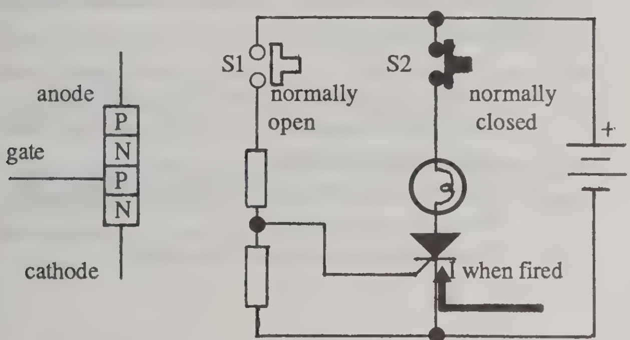
Often made from semiconductor material with its property of decreasing resistance with rising temperature, but with this device, in a 'calibrated' manner. Used to compensate for circuit temperature variations and for the measurement of temperature and power.

Silicon controlled rectifier (SCR)

Circuit symbol:



Also called a "thyristor", a 4-layered PNPN device.It is 'turned on' by applying a positive potential to the gate. Once 'fired', the gate has no further control and the only way to turn the SCR off is by reducing the anode voltage to nearly zero or removing it altogether.



When the battery is first connected
the SCR is off: lamp does not glow.

S1 momentarily closed: SCR 'fires'- lamp glows.

S2 momentarily opened: SCR reset- lamp extinguished.

Integrated circuits (I.C's.)

These contain numerous semiconductor circuits complete with capacitances and resistances, all of which are formed from one 'chip' of silicon and sealed in a small neat package.

Linear I.C's.

Circuit symbol:

The output is proportional to the input signal. They are used for timing, radio circuits, voltage regulation in power supplies and as amplifiers, (from small signal 'pre-amps' up to power amplifiers driving loudspeakers).

A variation is the Op-Amp- a high gain, direct-coupled amplifier with two inputs, one in phase with the output and other 180° out of phase). Used as summing amplifiers, (mixing many signals with out interaction), audio filters, (to pass a certain band of audio frequencies), and pre-amplifiers, (for small signals).

Digital I.C.'s

Information, (eg. numbers), is easiest and most accurately represented electronically by a series of two states: on and off, or, high and low, or, one (1) and nought (0). In these states information can be switched, added or subtracted, and so perform any desired task.

The 'heart' of these digital circuits are called "gates". They are basically a transistorised switch but with two inputs, the state of each determining what the state of the single output will be.

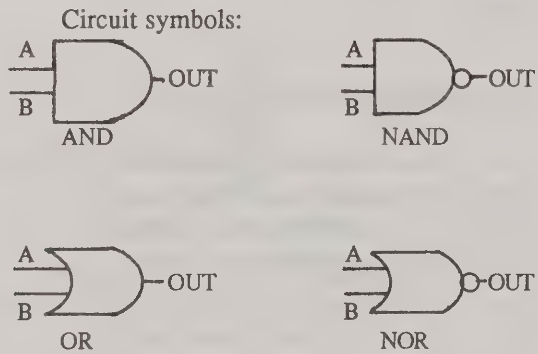
Construction of digital 'logic' IC's and gates can be in either of two types:

1. CMOS- Complementary metal oxide semi-conductor: they consume little power, operate over a wide 3 to 15 volt range, tolerate some power supply noise, have very high input impedance, generate little radio interference. But, they must be handled carefully to prevent being damaged by static electricity charges.

2. TTL- Transistor transistor logic: these are low cost high speed devices. Draw heavier current, narrow operating voltage around 5 volts, susceptible to interference from power supplies.

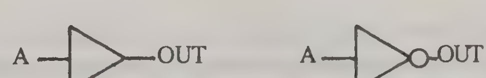
Gates

Circuit symbols:



Let one state be low or 0, and the other high or 1:

		OUT			
A	B	AND	NAND	OR	NOR
0	0	0	1	0	1
0	1	0	1	1	0
1	0	0	1	1	0
1	1	1	0	1	0



YES (Buffer)

NOT (Inverter)

	OUT —	
A	YES	NOT
0	0	1
1	1	0

Assignment 11

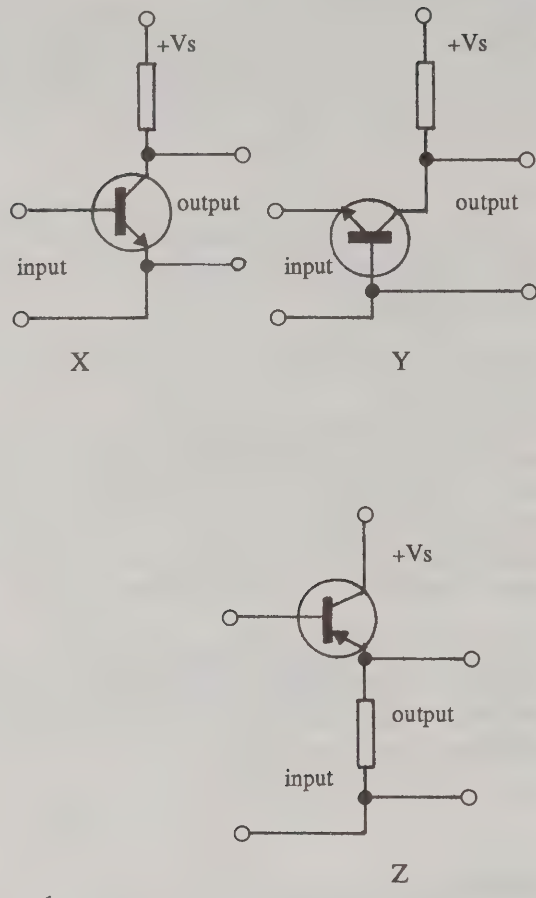


Figure 1.

1 In the circuits shown in Figure 1-

A. Z is a collector follower circuit
B. Y is a common collector circuit.
C. X is a common emitter circuit.
D. Z is a common base circuit.

2. Which of the circuits shown in Figure 1 has the highest voltage gain?

A. X an Y equally.
B. Z only.
C. X only.
D. Y only.

3. Which of the circuits shown in Figure 1 produce a 180 degree phase shift between input and output?

A. X and Y.
B. X and Z.
C. X only.
D. Y only.

4. A transistor operating in the common base mode has :

A. A high input impedance.
B. A low output impedance.
C. A high base impedance.
D. A low input impedance.

5. Which of the following are the characteristics of an amplifier stage using a transistor connected in the common collector mode?

A. The voltage gain is greater than unity.
B. The input impedance is high compared with the output impedance.
C. The input impedance is low compared with the output impedance.
D. The current gain is less than unity.

6. The use of direct coupling between individual transistor amplifier stages results in :

A. Reduced likelihood of thermal runaway.
B. Greater overall gain.
C. An increased bandwidth for the whole amplifier.
D. Less overall gain.

7. Applying negative feedback to a small signal amplifier stage :

A. Makes it more prone to instability.
B. Reduces its bandwidth.
C. Reduces harmonic distortion.
D. More than doubles power handling capability.

8. A thyristor -

A. Is a temperature dependent resistor.
B. Will not stop conducting until the supply voltage is removed.
C. Is a semiconductor used to prevent thermal runaway in transistorised power amplifiers.
D. Is a high power audio frequency transistor.

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

FET's and thermionics

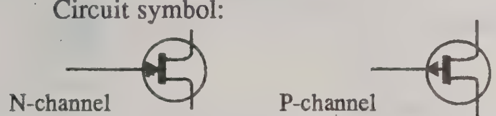
The field effect transistor (FET)

A semiconductor device where an electric field controls the current flowing through it. This field is obtained by applying voltage to an electrode called the 'gate'.

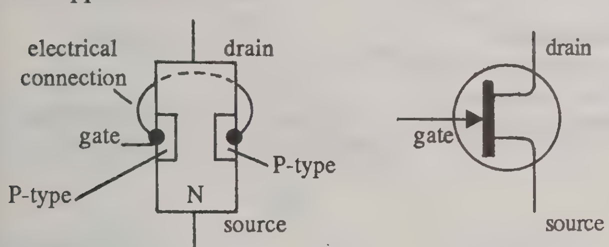
These are 'voltage-operated' devices, different to the transistor, ('current-operated'), which depends upon a base current to function.

Junction FET (JFET or JUGFET)

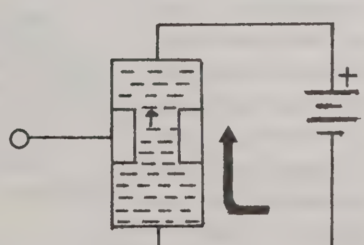
Circuit symbol:



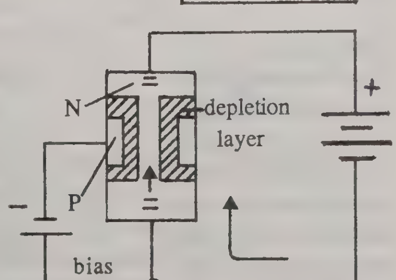
Normally a channel of N-type semiconductor with two P-type regions, (joined electrically together), diffused into opposite faces



FET operation i)
Current flows due to free electrons present in N-type channel being attracted to positive battery terminal.



FET operation ii)
Current reduced due to a reversed biased gate-source junction producing a 'depletion-layer'. In this layer free electrons are repelled away leaving an area

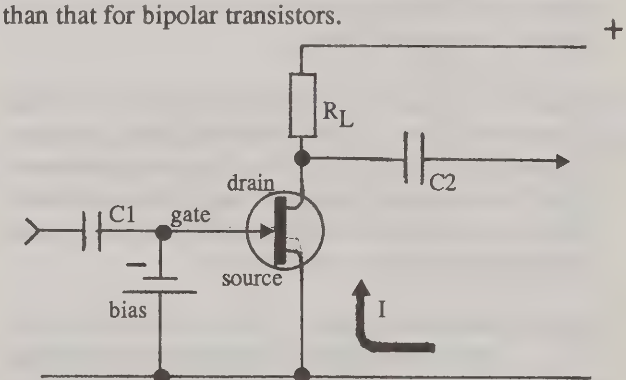


void of free electrons. Therefore, because less volume now exists in the channel to carry electrons, the source-drain current reduces accordingly. Too large a gate voltage will 'pinch-off' the drain current and reduce it to virtually zero.

For P-channel FET's the effects are the same but all polarities are reversed.

The junction FET amplifier

Because the gate does not draw any current for its operation, the input impedance is alot higher, (1MΩ), than that for bipolar transistors.



common-source amplifier

The bias battery sets the gate at a negative potential for class A operation. The signal, fed via C1 to the gate, is superimposed on this bias.

The now varying gate potential produces a changing depletion layer, causing a large changing drain current. An amplified voltage is tapped off at the source and fed out via C2.

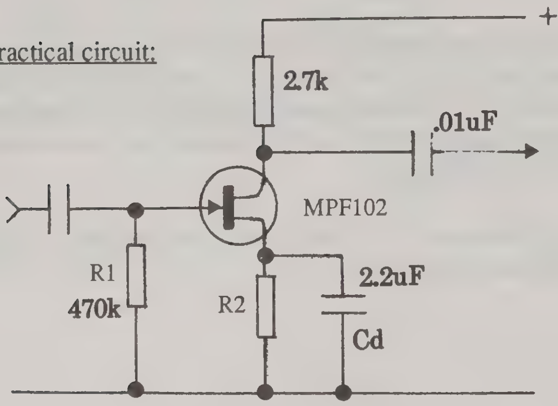
Other configurations may be used, namely that of the common gate, and source follower. The same comparisons hold as those for the transistor in regard to voltage gain, relative impedances, and phase change.

Junction field effect transistors may be biased for the other classes of operating conditions.

Mutual conductance (gm)- Also called transconductance: a measure of a FET's amplification ability by taking into account the effect that the input voltage has on the drain current.

$$gm = \frac{\text{change in Id}}{\text{change in Eg}}$$

Practical circuit:



Junction FET common source amplifier

Negative bias is needed for the gate and this is cleverly derived by inserting R2. Current is flowing through R2 and so lifts the source to some positive potential with respect to earth. The gate, having no fixed voltage applied, is at 0 volts or earth.

Therefore the source terminal is positive (+V) with respect to the gate (0V), but, from the gates perspective the gate is less positive, or effectively 'negative', with respect to the source, (where the electrons are leaving)! We do in fact therefore have negative bias, the amount being dependant upon the value of R2.

R1 performs two tasks:

i) to keep the gate at (0V). This will keep the bias looking 'negative' with repect to the source. (It will do this because R1 is not passing any current and so the earth potential (0V) will appear at the other end which is on the gate). If this is not done, the gate potential could drift up in a positive direction causing the FET to conduct too much current.

ii) set the input impedance of the stage.

Cd is a de-coupling, or by-pass capacitor, which holds the source at a stable d.c. potential irrespective of current fluctuations caused by the signal, and so maintain good stage gain.

GaAs FET

A special junction FET made with gallium arsenide semiconductor compound and gives low-noise amplification at u.h.f. and higher, being useful for both small signal and high power applications.

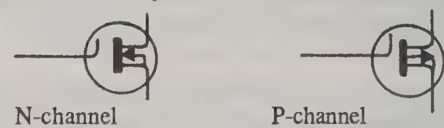
Insulated gate FET (IGFET), Metal-oxide semiconductor FET (MOSFET)

The gate is insulated from the channel by a thin layer of insulating glass giving an even higher input impedance. The bias could be either polarity because it is impossible to draw gate current. Care though must be used in their handling, for they can easily be damaged by static electricity charges, (which could happen if fingers touch their leads).

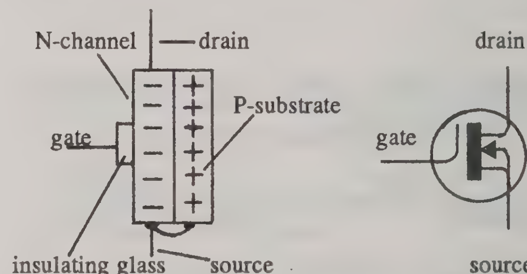
1. Depletion mode type

a) Single Gate:

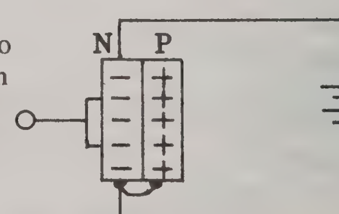
Circuit symbol:



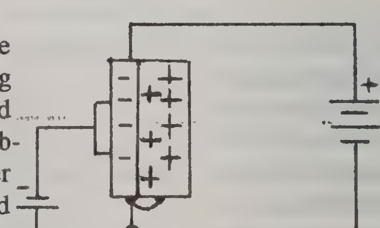
Commonly a N-type channel is placed next to a P-type 'substrate'.



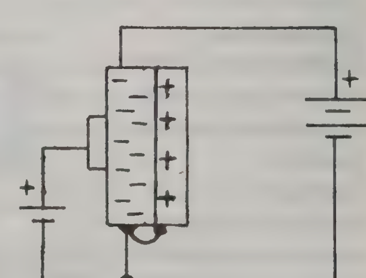
Operation i)
current flows due to free electrons in N-type channel.



Operation ii)
current reduced due to the channel being narrowed or depleted by 'holes' in the sub-strate coming over towards the field caused by the gates negative polarity.

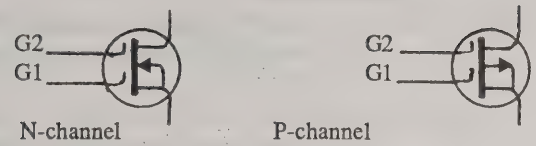


Operation iii)
more current flows because channel is larger due to positive bias repelling holes in substrate. No gate current flows be-cause gate is insul-ated from channel.



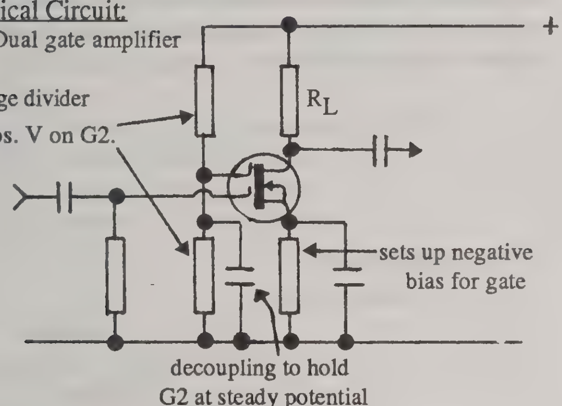
b). Dual Gate:

Circuit symbol:



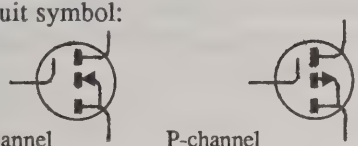
The signal is applied to Gate 1 which is 'negatively' biased. Gate 2 has positive voltage applied, the potential of which can be varied to alter the gain of the stage.

Practical Circuit:



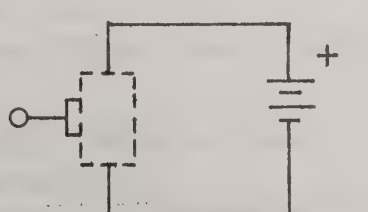
2. Enhancement mode type

Circuit symbol:

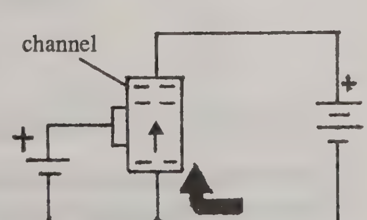


These MOSFETS are specifically constructed so as to have no channel at zero gate voltage.

Operation i)
no current flows because channel does not exist.



Operation ii)
Current flows because N-channel is now formed by the positive bias. No gate current flows because gate is insulated.



Enhancement mode types when used as amplifiers are biased similar to bipolar transistors:

Bias for: class A = positive
class B = small positive
class C = zero

VMOS FET

A special type of enhancement mode insulated-gate FET that not only amplifies small and high power signals but over a wide range of frequencies from audio to v.h.f.

Thermionics

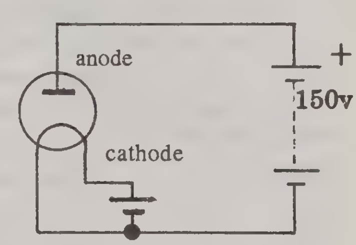
Thermionic Emission- electrons that are emitted from a hot 'filament', and form a negative potential around itself called a 'space-charge'. Devices using this principle are often called 'valves' or 'tubes'.

The thermionic diode

Circuit symbol:

A filament, (cathode), and another electrode, (anode or plate), placed inside an evacuated glass tube.

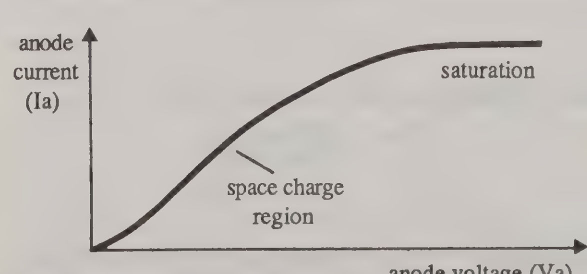
Current flows because electrons in space charge surrounding hot cathode are attracted to the high positive anode voltage.



When the anode-cathode voltage is reversed in polarity no current flows. Can be used for rectification.

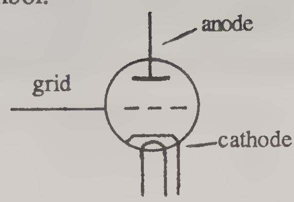
Indirectly heated cathode- one which is separate from the filament physically and electrically, but is heated by it. This enables use of materials that more readily emit electrons such as pure nickel.

Saturation- the point where if the anode voltage is increased higher, no more increase in anode current is possible because all the electrons in the space charge are already being collected by the anode.



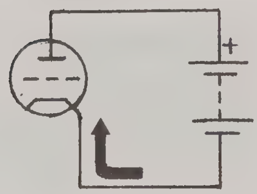
The triode

Circuit symbol:



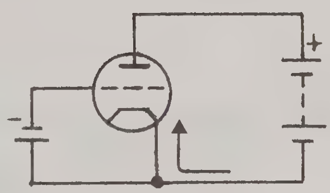
Triode operation i)

Current flows

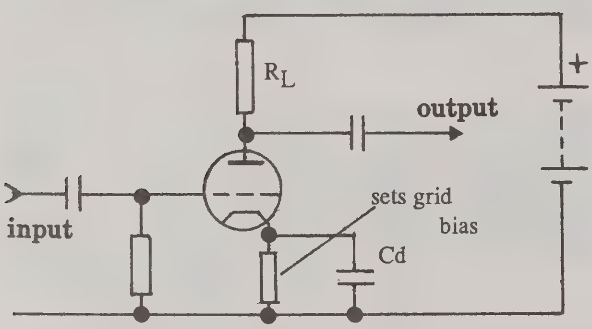


Triode operation ii)

Current reduced, negative bias on grid repels some electrons and prevents them from reaching anode.



The triode amplifier



Similar to the junction FET amplifier. The input impedance is high because no grid current flows.

Valve parameters with typical values for triodes:

Amplification Factor (μ)- typically 20.

$$\mu = \frac{\text{change in Ea}}{\text{change in Eg}}$$

Mutual Conductance (gm)- transconductance, typ. 3000μmho.

$$gm = \frac{\text{change in Ia}}{\text{change in Eg}}$$

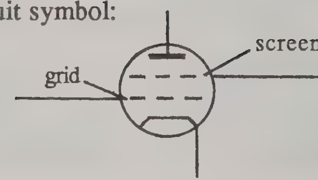
Anode Resistance (Ra)- typically 7KΩ

$$Ra = \frac{\text{change in Ea}}{\text{change in Ia}}$$

Relationship- $\mu = gm \times Ra$

The tetrode

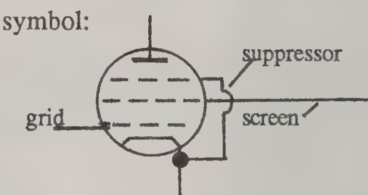
Circuit symbol:



The screen has a positive potential applied. Inter-electrode capacitance, such as that found in the triode, is reduced, so more gain is possible at higher frequencies. A disadvantage though is 'secondary-emission'. This is the dislodging of electrons from the anode when it is hit by high speed electrons. The dislodged electrons are then attracted to the positive screen, reducing the current that would normally flow in the anode, and so give the tetrode a 'negative-resistance' characteristic.

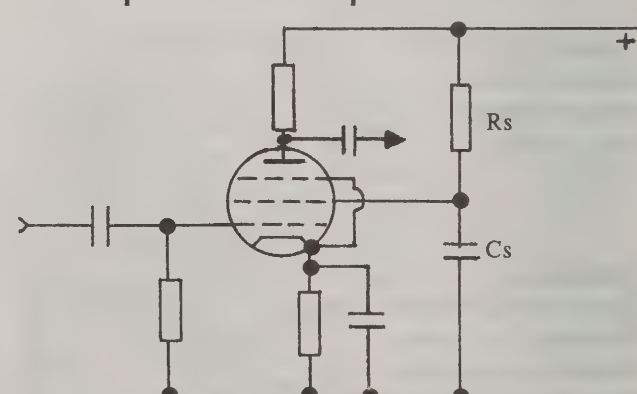
The pentode

Circuit symbol:



The suppressor is connected to the cathode, giving it a low potential and thereby repelling the dislodged secondary electrons away from the screen and back towards the anode.

The pentode amplifier



Rs supplies a positive voltage to the screen and Cs hold this point steady from signal fluctuations.

Valves in amplifiers are all voltage operated devices similar to the FET, and may be used in common-cathode, common grid, cathode follower configurations, and in classes A, B, AB1, AB2, and C .

Assignment 12

1. If the gate-to-source voltage of a junction field effect transistor is made equal to zero -

   A. A condition known as "pinch off" occurs.
   B. The source current will be zero.
   C. The depletion layer width will increase.
   D. The maximum possible drain current will flow.

2. Making the gate of an N channel field effect transistor more negative with respect to its source will :

   A. Increase the source to drain resistance.
   B. Increase the drain current.
   C. Decrease the gate current.
   D. Increase the source current.

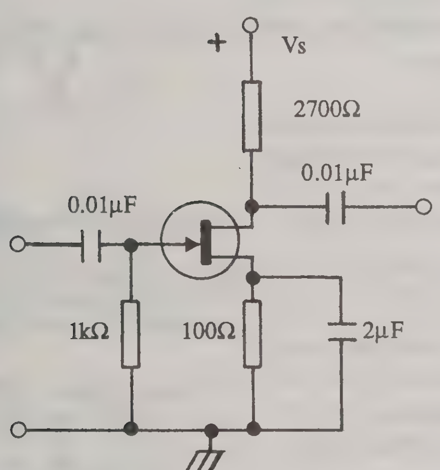


Figure 1

3. The circuit shown in Figure 1 would be suitable for use with -

   A. A low impedance dynamic microphone.
   B. An electret microphone.
   C. A high impedance dynamic microphone.
   D. A crystal microphone.

4. Which of the following applies to a MOSFET?

   A. Has a high gate-drain capacitance.
   B. Gives best linearity when supplied with a high gate current.
   C. Can be damaged by static electricity whilst it is being handled.
   D. Gives best linearity when supplied with a high base current.

5. When the operating conditions of a thermionic valve are such that the anode is collecting all possible electrons that the cathode can emit, the valve is said to have reached -

   A. Saturation point.
   B. Cut-off point.
   C. Maximum useable current point.
   D. Maximum anode dissipation.

6. The suppressor grid in a pentode valve -

   A. Reduces unwanted emission from the cathode.
   B. Acts as a shield between the control grid and the screen grid.
   C. Reduces the effect of secondary emission from the anode.
   D. Prevents the undesirable consequences of Miller effect.

7. Which of the following methods could be used to obtain grid bias for a pentode valve?

   A. A resistor connected in the suppressor lead.
   B. A resistor connected in the cathode lead.
   C. A resistor connected in the plate lead.
   D. A resistor connected in the screen lead.

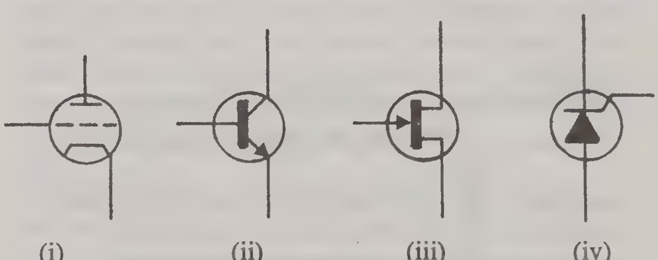


Figure 2

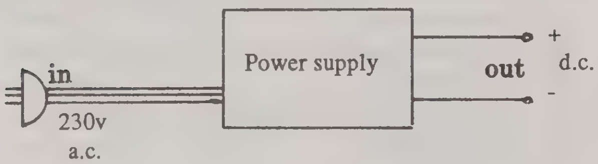
8. Which of the devices represented by the symbols shown in Figure 2 will not act as a small signal amplifier?

   A. i
   B. ii
   C. iii
   D. iv

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

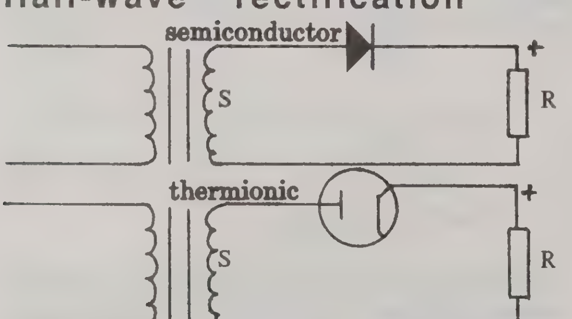
Mains operated power supplies

Up until now our circuits have been supplied with an e.m.f. from a battery. This is normal for portable and mobile equipment, but when operating from home it is more convenient and less expensive to utilise the a.c. 'mains' from the ordinary household power point.



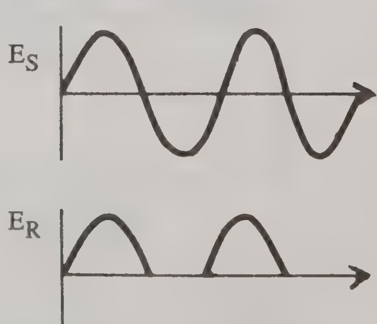
To obtain suitable voltages, transformers are used, and as most circuits require a d.c. voltage to function, diodes are used for rectification. (An exception is valve filaments which usually operate on a.c. without any rectification. They are wired in parallel and fed from a separate 6.3 volt secondary winding on the transformer). The rectified d.c. is then 'smoothed-out' to give a voltage as good as that obtainable from a battery.

Half-wave rectification



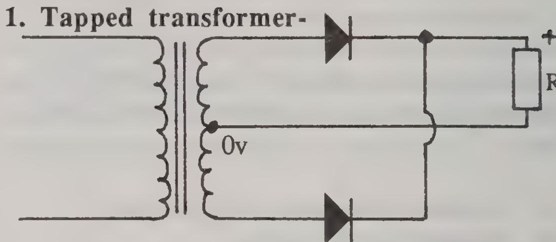
The transformer steps the voltage up or down which is then rectified.

In this example the diodes conduct on the positive halves of the waveform.

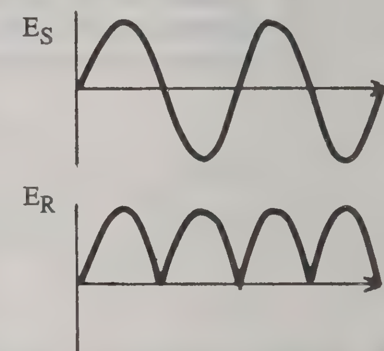


Full-wave rectification

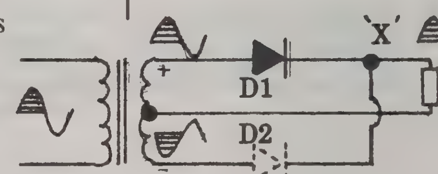
1. Tapped transformer-



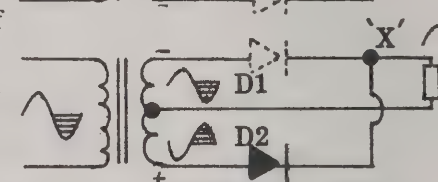
A centre-tapped transformer gives a 'mirrored' waveform which has two positive going portions for every cycle.



On the first half of the cycle D1 conducts and D2 is reversed biased.

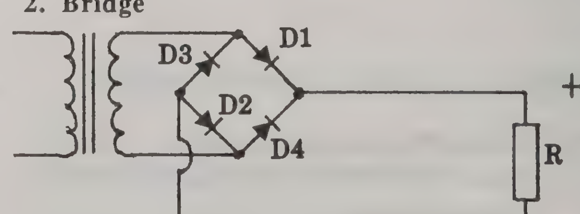


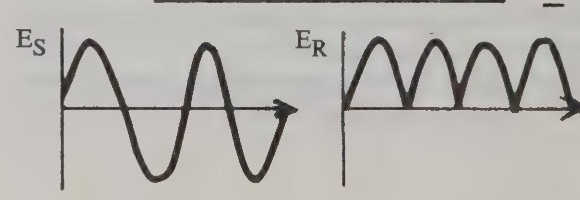
On the second half of the cycle D2 conducts and D1 is reversed biased.



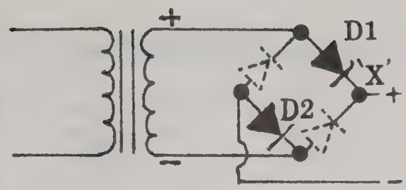
Both diodes recombine their positive going portions at the same point, marked with an 'X', resulting in a continuous positive going voltage.

2. Bridge

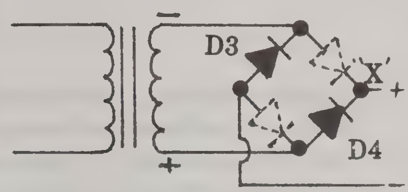




For the first half of the waveform D1 and D2 conduct to point 'X'.



On the second half of the waveform D3 and D4 conduct also to point 'X'.



Voltage regulation %

This represents the variation of the power supply output voltage when delivering maximum current on full load to that of no load at all.

$$\text{PERCENT REGULATION} = 100 \times \frac{(\text{E no load} - \text{E load})}{\text{E load}}$$

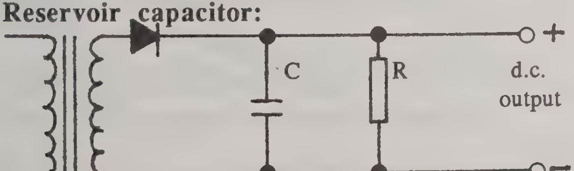
A good supply would have a low variation percentage.

Smoothing filters

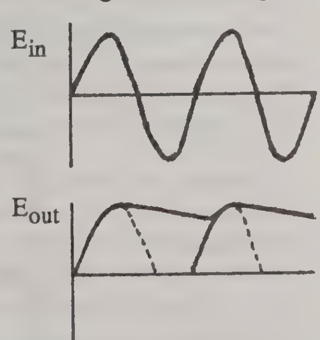
Although the voltage is now rectified it is not steady, but fluctuating up and down with 'ripple'. To smooth this and make a flat steady voltage a 'filter' is used.

1. Capacitive input filter-
Used with semiconductor rectifiers.

a) Reservoir capacitor:



The capacitor, usually an electrolytic, acts like a 'reservoir' and charges up to the peak value of the rectified waveform and holds most of this charge during the interval before the next peak.

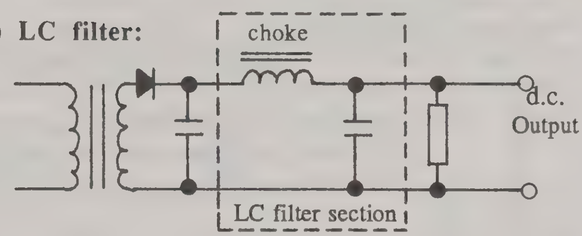


R is a 'bleeder' resistor and ensures the capacitor is discharged, (for safety), when the power is switched off, and also helps improve voltage regulation by providing a minimum load so that the supply always delivers some current.

Output voltage- this will assume a value very close to the secondary's peak voltage:

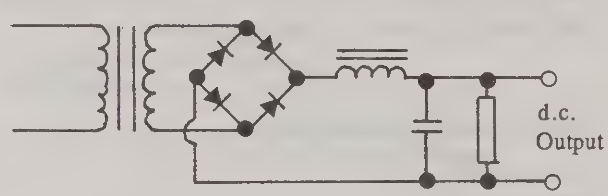
$$\text{Eout} = 1.4 \times \text{E sec rms}$$

b) LC filter:



Improved smoothing is achieved. The inductor offers reactance to the ripple and is called a 'choke'.

2. Choke input filter-
The choke is placed at the input. Although this type of filter causes some drop in voltage compared with the capacitor-input type, it does provide better regulation and permits higher currents, especially when using thermionic rectifiers.



To stop it looking like a capacitor input filter, and thereby losing the good regulation possible, the choke's inductance must be above a certain value called the "critical inductance". This critical value changes though with the amount of current being delivered, and in practice can be hard to stay above, especially with light loads. Under these conditions the critical inductance rises, necessitating a larger, more expensive choke if we wish to retain the good regulation possible.

At the very extreme with no load at all, the inductance required is so large it is impossible to achieve. Therefore, a bleeder resistor must always be used to ensure that a minimum amount of current will always flow.

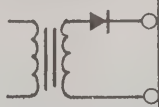
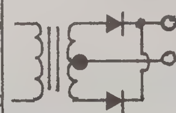
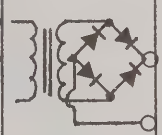
The choke input filter cannot be used with the half-wave rectifier because of the zero current every half cycle.

Swinging choke- a specially constructed input filter choke, the inductance of which changes automatically with the current flowing through it and thereby staying above the critical value determined by the same current at that time.

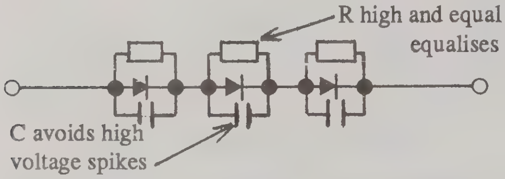
They are smaller and less expensive than the large chokes that would otherwise have had to of been used in applications with large current variations, (such as supplying a class B power amplifier).

Rectifier considerations

Peak inverse voltage (PIV)- The maximum voltage a diode can withstand when it is reversed biased, (not conducting). This must be considered when designing rectifier circuits.

FILTER TYPE	HALF-WAVE	FULL-WAVE	
		CTRE-TAPPED	BRIDGE
↓			
No filter, res. load	1.4 E rms	2.8 E rms	1.4 E rms
Cap. Input	up to 2.8 E rms	2.8 E rms	1.4 E rms
Choke i/p	cannot use	2.8 E rms	1.4 E rms

Diodes in series- When the PIV rating of a single diode isn't high enough for the application:



The fuse

Circuit symbol: 

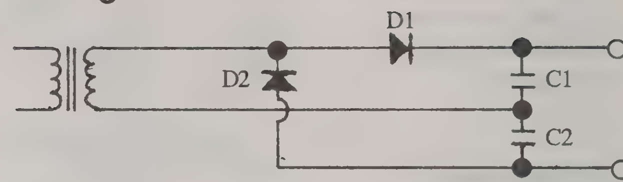
A means to 'break' a circuit drawing excess current and so prevent any further damage. The fuse consists of a thin piece of conductor that melts at a specified current and is often housed in a small glass cartridge .

Earthing and safety

The earth in the 'mains' is connected to a rod buried in the ground, just outside the house, ensuring it is at 0volts. The chassis of the power supply is normally connected to this earth via the mains plug. All transformers, chokes and capacitor cases are connected to the chassis. This protects against electric shock for if a fault did develop and the chassis tried to become 'live' it would immediately short to earth(0v) and blow the fuse.

The fuse and on/off switch are connected on the primary side of the transformer and <u>must</u> be in the phase ('live') lead. Live voltages should never be left exposed but covered or made inaccessible.

Voltage doubler



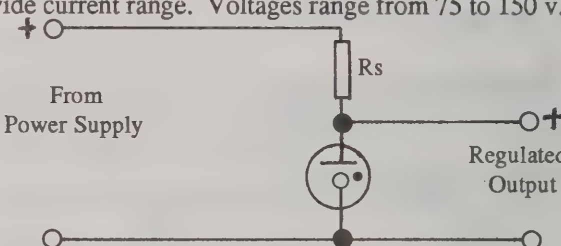
In the first half of the cycle D1 conducts and charges C1 to the positive peak of the a.c. waveform.
During the second half of cycle D2 conducts and charges C2 to the negative peak of the a.c. waveform.
Thus the voltage at the output is: 2 x 1.414 rms.
The PIV across each diode is 2.8 E rms.

Mercury vapour rectifiers

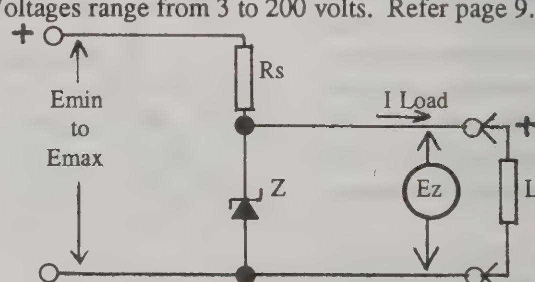
Are thermionic, and handle high voltages and current. The forward voltage drop is virtually constant regardless of the load current. Before the anode voltage is applied though, the filament must be pre-heated so as to vapourise the liquid mercury and thus prevent 'ionic bombardment'. They can cause radio interference.

Voltage regulation

1. Cold cathode tube- Filled with a gas capable of being ionised. Their voltage drop is constant over a wide current range. Voltages range from 75 to 150 v.



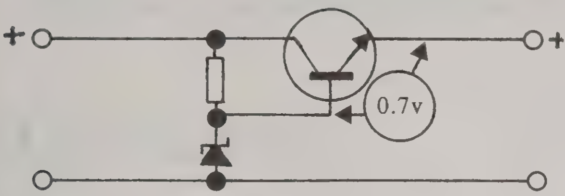
2. Zener diode- more reliable, cheaper, and smaller than the cold cathode tube. Voltage drop is constant above a 'zener' or 'avalanche' level when reversed biased. Voltages range from 3 to 200 volts. Refer page 9.3.



To calculate Rs:

$$Rs = \frac{E\,Rs}{I\,Rs} \quad \text{(ohms law)} \qquad = \frac{E\,min - E\,z}{I\,load + 10\%}$$

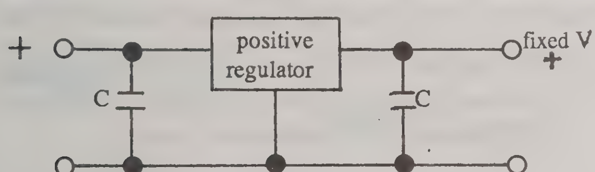
3. Transistor- regulation for higher currents.



The transistor is forward biased by a regulated voltage from a zener diode on its base. The base-emitter junction will always drop 0.7 volts across itself due to the junction barrier potential. Therefore, whatever the voltage might be on the collector, (regulator input), the emitter voltage, (the output), will be always be held just 0.7v below the stable zener voltage on the base.

A disadvantage with the circuit above is that there is no 'current-limiting' and so the transistor may be destroyed if the load becomes 'shorted'.

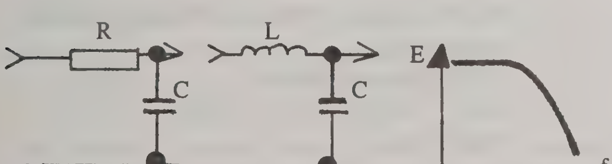
4. Three-terminal I.C.- very popular, easy to use, and have 'current-limiting' so are virtually destruction proof. Two types: adjustable voltage, or fixed voltage (available in 5, 12, and 15 volt values).



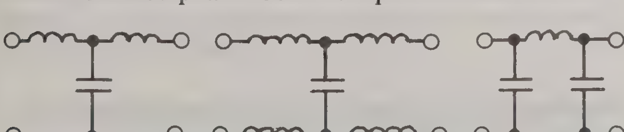
Audio and r.f. filters

Passive filters

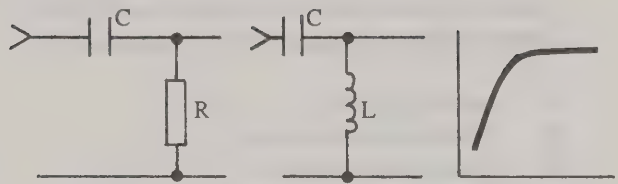
1. Low-pass- zero insertion loss up to some critical or 'cut-off' frequency and then rejection above this.



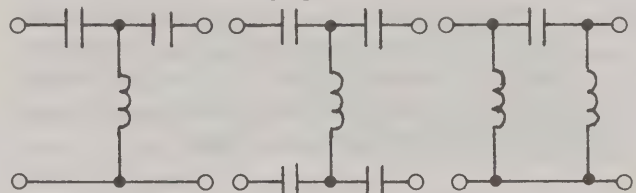
Looking at the circuits above, they are essentially voltage dividers. Low frequencies are present at the output. The reactance of C is high for them, thereby dropping more of these low frequency voltages across C which is the output. Other low-pass circuits:



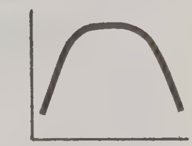
2. High-pass-

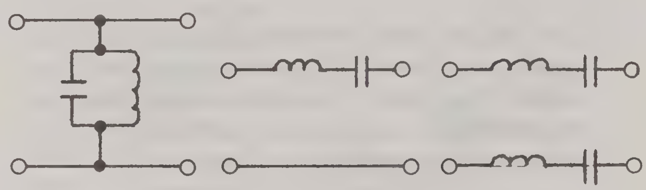


High frequencies are present at the output. The low reactance of C for higher frequencies, means that they will not drop across C but be present at the output across R or L. Other high-pass circuits:

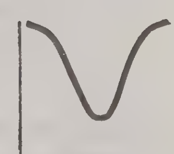


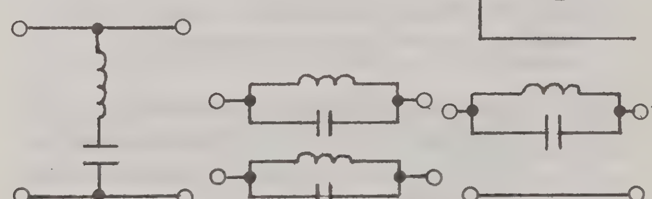
3. Bandpass- only a selected range of frequencies are present in the output.





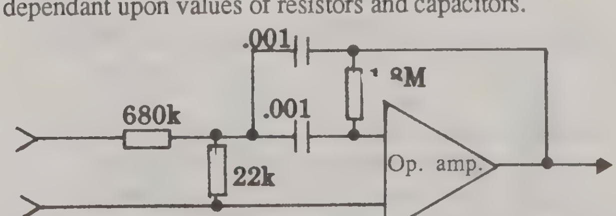
4. Bandstop- Rejects a band of frequencies.





Active filters

These require an external power source to function, (not shown), and are often built around an IC Op. Amp. They have unity gain or greater, are compact, and able to have variable Q, centre, or cut-off frequencies dependant upon values of resistors and capacitors.



Active bandpass 750Hz audio filter

Assignment 13

1. When compared with the inductor input type, a capacitor input type power supply filter gives-

   A. Better regulation.
   B A higher output voltage.
   C. A higher output current.
   D. A lower peak diode current.

2. A power supply uses a half wave rectifier to supply a capacitor input filter. The transformer secondary winding delivers 12 volts RMS to the rectifier. Approximately what peak inverse voltage will be developed across the rectifier?

   A. 12 volts.
   B. 17 volts.
   C. 24 volts.
   D. 34 volts.

3. The peak voltage developed across each non-conducting diode in a full wave bridge rectifier system that feeds a capacitor input filter is approximately equal to the RMS value of the supply voltage multiplied by a factor of -

   A. 0.7, B. 1.0,
   C. 1.4, D. 2.8.

4. The main reason for providing a substantial mains earthing point on electronic equipment is to :

   A. Bypass all spurious signals to earth.
   B. Provide a path for r.f. to be bypassed to earth.
   C. Provide a path for mains fault currents to be passed to earth.
   D. Enable the equipment to operate most efficiently.

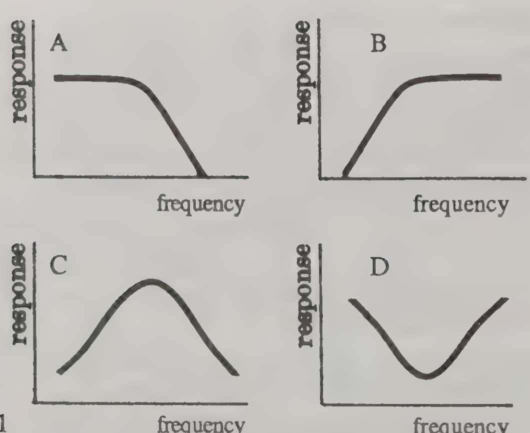


Fig. 1

5. Which of the graphs shown in Figure 1 represent the response of a band pass filter?

   A. A.
   B. B.
   C. C.
   D. D.

6. A low-pass filter is a device which :

   A. Passes currents with frequencies higher than nominal cut-off frequency with minimum attenuation, while frequencies below this frequency are highly attenuated.
   B. Passes a band at low frequencies.
   C. Eliminates a band at high frequencies.
   D. Passes current having frequencies lower than nominal cut-off frequency, and highly attenuates those with frequencies above.

7. The regulation of a power supply with a no load voltage output of 126.5 volts and a full load voltage output of 115 volts is :

   A. 9.1%
   B. 10%
   C. 11.5%
   D. 12.7%

8. An amplifier is said to be linear if -

   A. It has a regulated bias supply.
   B. The bias current remains constant over the input cycle.
   C. It produces no distortion.
   D. Power output versus voltage input is a straight line.

Questions 1 to 5 and 8 in this assignment are reproduced from past examination papers courtesy of RFS.

LESSON 14

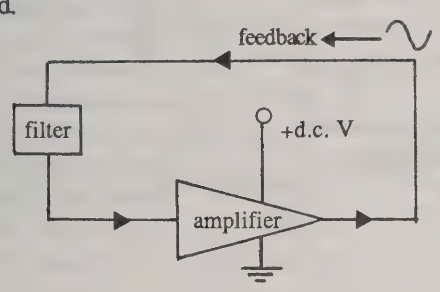
Oscillators

Positive feedback- the feeding of the output of an amplifier back to its input, 'in-phase'. The initial signal is reinforced and this 'regenerative' process increases amplification.

Oscillation- the value of a quantity, that is continually changing so it passes through maximum and minimum values, such as a swinging pendulum or an a.c. waveform.

The oscillator

A circuit that converts d.c. power into an a.c. waveform and is essentially an amplifier with positive feedback via a filter to determine the frequency of oscillations produced.



When d.c. voltage is applied to the amplifier, the transistor, (or other active device), will 'turn-on' and pass a current that will be varying slightly from moment to moment as a random number of electrons travel through it.

A small 'noise' voltage is generated at the output containing a mixture of alternating currents of varying amplitudes and of all possible frequencies.

The output is passed through a filter which 'selects' only those noise voltages of the wanted frequency. (A tuned circuit is used in r.f. oscillators).

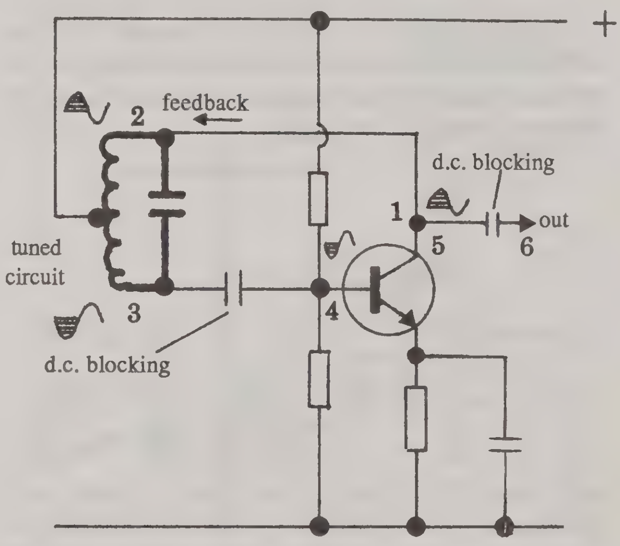
These are fed back to the input in such a manner that they aid or add to the original noise voltage, (in phase), are amplified, fed back and then amplified over and over again. A strong oscillation is produced, some of which can be coupled to an external circuit.

The oscillator is used in transmitters and most receivers and can be of fixed frequency or tuneable, (variable frequency oscillator or v.f.o.).

The L.C. oscillator

Used for generating r.f. frequencies. The L.C. tuned circuit is often called a "tank circuit" because with each cycle it stores much more energy than is used by the external circuit. The ratio of energy stored to the energy used is equal to the Q of the tank circuit, the higher the better for good frequency stability.

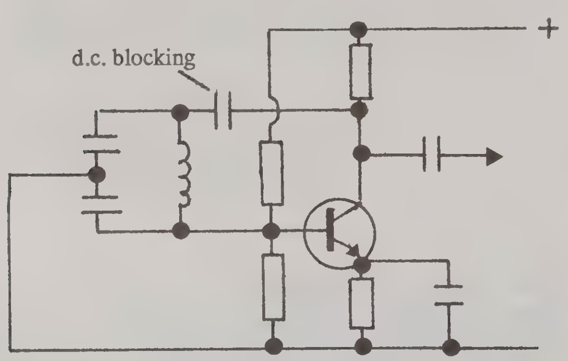
1. Hartley oscillator- uses centre-tapped coil.



Essentially a common emitter amplifier with voltage divider bias. (See page 10.2) In the oscillator circuit above the collector obtains its voltage via the coil and because of this is called 'series-fed'.

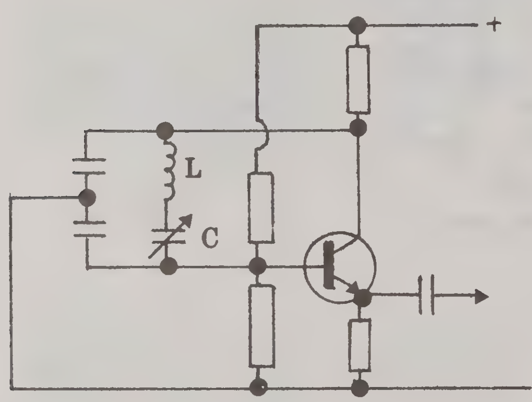
1. assume a positive going noise signal,
2. this is fed to top of the coil which is part of a 'filter' thats shown here in thick lines,
3. phase is changed 180° by centre-tapped coil,
4. negative going signal now fed to base,
5. signal is amplified and now in phase with original signal,
6. oscillation will occur if gain of stage is greater than 1 and may be taken off here. (In any oscillator, insufficient feedback or gain, may mean oscillation will cease with the application of, or an increased in, a load).

2. Colpitts oscillator- uses two 'tapped' capacitors.



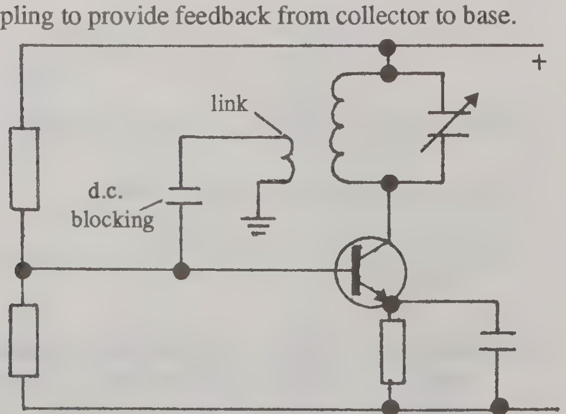
The collector signal is changed 180° in phase by feeding it back to two 'centre-tapped' capacitors.

3. Clapp oscillator- a capacitor is inserted in series with the coil to reduce the tuned circuit loading and so minimize any 'drift' in frequency, and also lower the harmonic content of the output.



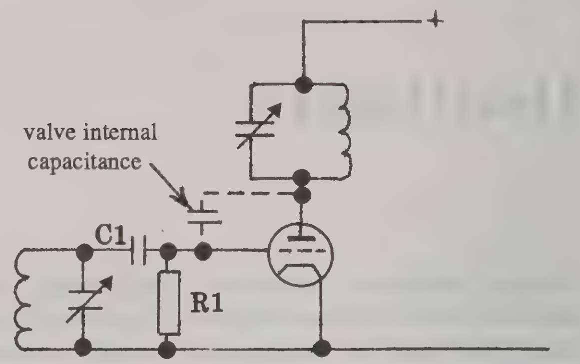
C and L determine the frequency.

4. The Armstrong oscillator- uses transformer coupling to provide feedback from collector to base.



The link must be connected the correct way around to ensure a 180° phase change.

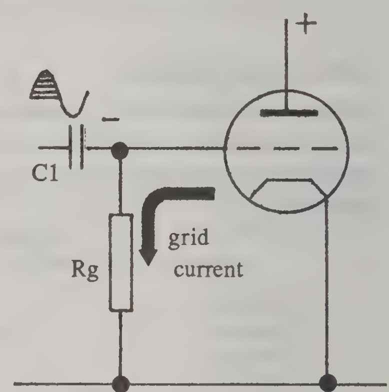
5. Tuned anode-tuned grid- relies on internal valve capacity to provide a feedback path.



The coils in the two tuned circuits are not magnetically coupled. Feedback through the valve will be in phase with the input only when the anode circuit appears inductive by being tuned to a slightly higher frequency than the grid circuit.

The valve generates its own bias with C1 and R1 in a manner called 'grid-leak bias'.

This is where the positive portion of the signal causes grid current to flow through Rg, charging C1 and producing a negative potential on the grid.

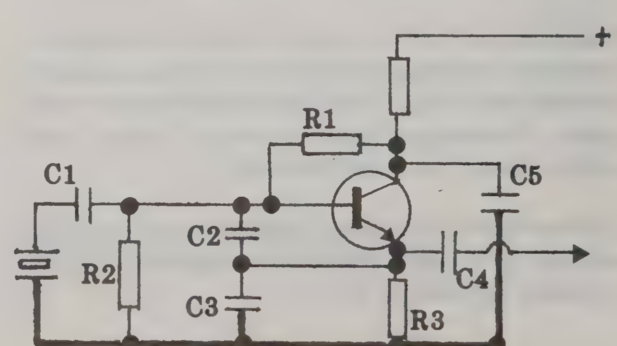


Grid leak bias works with FET's also.

The crystal oscillator

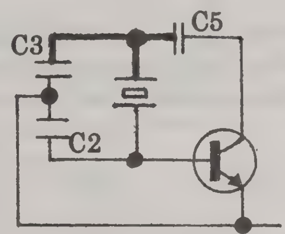
These use a quartz crystal, (refer page 8.2), as the tuned circuit and is very stable. Essentially they are fixed frequency and often different crystals are selected by a switch. The crystal may be 'pulled' a small amount (approximately 0.025%) from its fundamental frequency by external capacitances. (This is done in variable crystal oscillators or v.x.o.'s).

1. Colpitts (transistor version)-



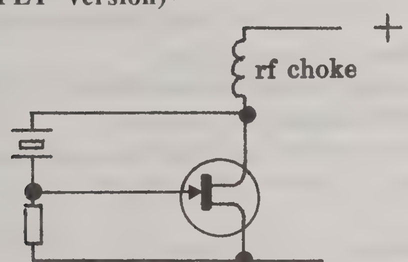
C1 is a d.c. blocking capacitor, although this is often omitted because of the equivalent 'natural' capacitors inside the crystal itself. Although this circuit may look different from our L.C. Colpitts oscillator, when re-drawn like it is here, it is really the same. The feedback path is actually via the earth line between C5, C3 and the crystal, (shown in heavy line).

R1 and R2 set the bias, with R3 being the load resistor.

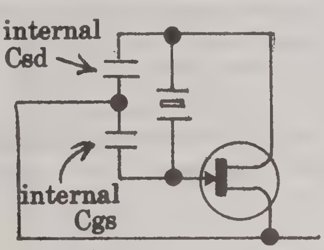


simplified equivalent circuit

2. Pierce (FET version)-



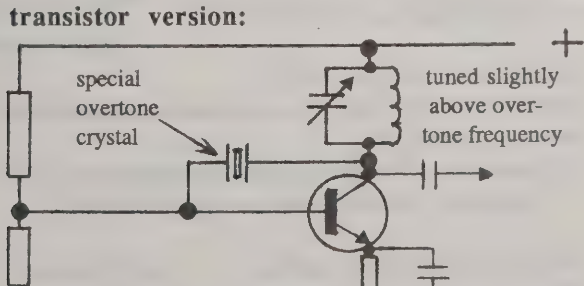
The crystal is connected between the drain and gate. The choke has a high reactance at r.f., so it behaves like a load 'resistor'. When redrawn here, it is essentially a colpitts and relies upon the internal capacitances of the FET to provide the tapped capacitor.



simplified equivalent circuit

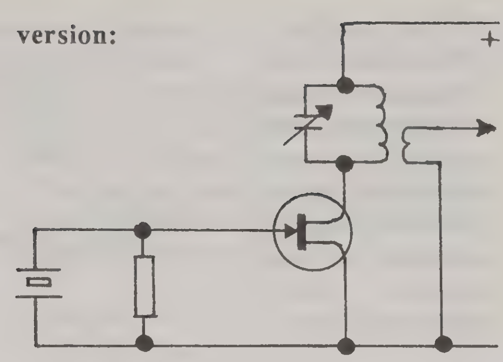
3. Overtone- normal crystals are only available up to 30MHz. For crystal controlled oscillators above this, special 'overtone' crystals are used. These can be designed to operate on either the 3rd, 5th or 7th harmonic of a fundamental frequency. They have high content of the particular harmonic and a tuned circuit as the load 'resistor' ensures oscillation at the correct frequency.

a) transistor version:



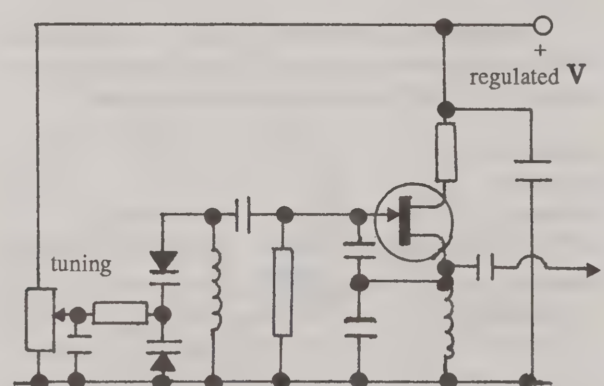
C is tuned at slightly above the crystal overtone frequency.

b) FET version:



'Tuned drain-tuned gate' with drain tuned circuit resonant slightly above the crystal overtone frequency.

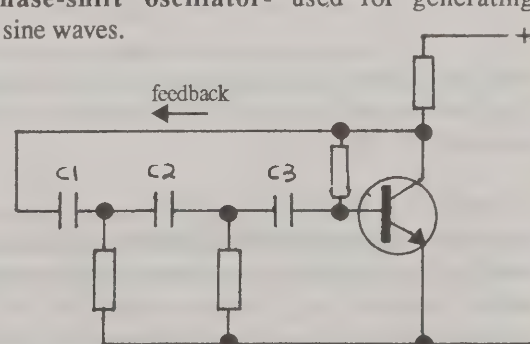
Variable capacitance diode oscillators



Two diodes are used back to back with reverse bias applied equally. Tuning is accomplished by changing this bias with the potentiometer, acting as a voltage divider.

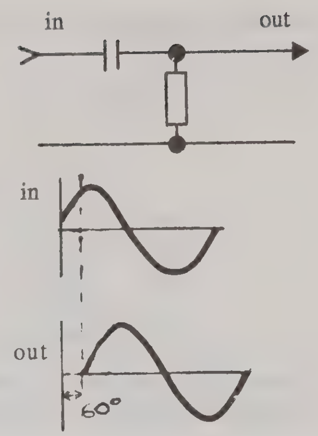
RC oscillators

1. Phase-shift oscillator- used for generating audio sine waves.



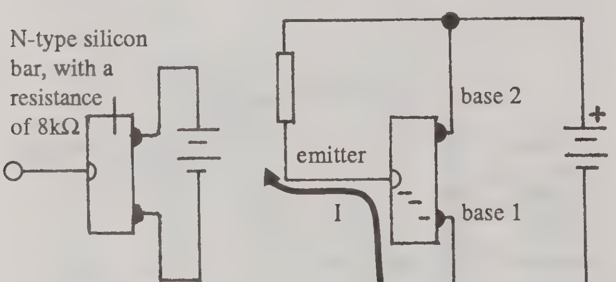
The collector signal is fed back to the base via a series of R.C. phase-shift networks.

In this oscillator, three networks each produce a 60° phase-shift giving a total of 180°. The third network consists of C3 and the internal resistance of the transistor's base-emitter junction.

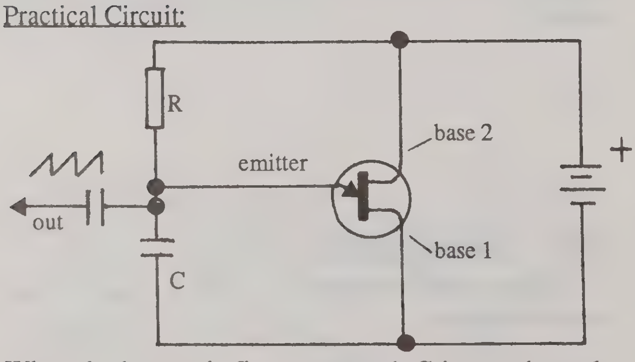


Oscillation will occur at a frequency determined by the particular set of values that cause the phase to shift by 60° in each network.

2. Relaxation oscillator- uses a unijunction transistor that turns on and off in the emitter - base 1 region, as a result of what bias is on the emitter.



Practical Circuit:



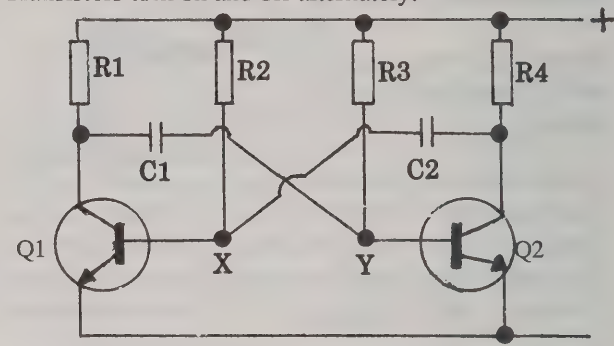
When the battery is first connected, C is not charged. Therefore the emitter is at earth potential (0v) and the unijunction is off.

C charges via R and a point is reached when the unijunction suddenly turns on, providing a discharge path for C via the now low resistance emitter-base 1 region.

C is now discharged, so the unijunction turns off. The process repeats, resulting in a 'saw-tooth' waveform.

3. The mulitvibrator- Two stages coupled so that the input of each is derived from the output of the other. The method of operation does not need to be known although it is included here for completeness.

a) Astable multivibrator- not stable, 'free-running', oscillates producing a 'square-wave'. Transistors turn on and off alternately.

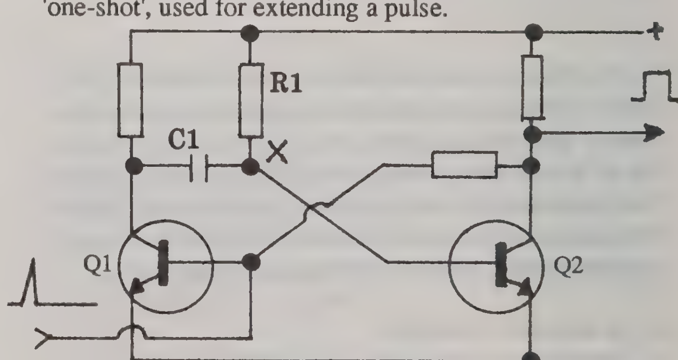


Assume Q1 is on, Q2 is off.
C1 charges via Q1, C1, and R3.
Point Y becomes high positive,
Q2 now turns on, and its collector goes low.
Base Q1 is then low, Q1 turns off.

C2 charges via Q2, C2, and R2.
Point X becomes high positive,
Q1 now turns on, and its collector goes low,
Base Q2 now is low, Q2 turns off and the process repeats itself.

'On' and 'off' times and frequency are determined by the time constants of R1-C1 and R4-C2.

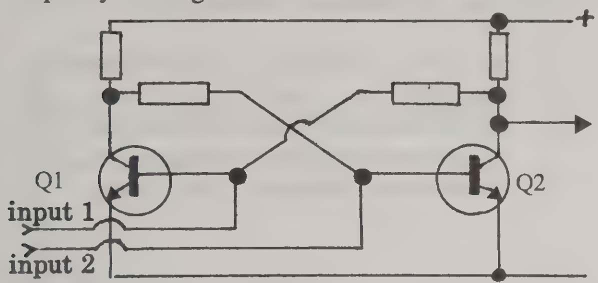
b) Monostable multivibrator- one stable state, 'one-shot', used for extending a pulse.



Assume Q2 is on, Q1 is off
Positive pulse in, turns Q1 on, collector Q1 goes low.
Base Q2 is then low,
Q2 now turns off, and its collector goes high,
(pulse out while C1 charges via Q1, C1, R1).

Point X becomes high positive,
Q2 turns on and its collector goes low.
Base Q1 is then low, Q1 turns off and resumes its original state.

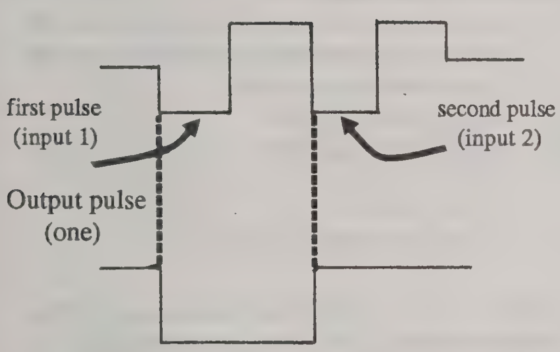
c) **Bistable multivibrator-** two stable states, 'latch', 'flip-flop', 'memory unit', used for counting and frequency dividing.



Suppose Q1 is on, then its collector will be low.
Base Q2 is then low,
Q2 therefore is off and its collector high.

Negative pulse to input 1:
Q1 turns off and its collector goes high,
Base Q2 now high,
Q2 turns on and its collector goes low.

Negative pulse to input 2 will reset circuit back to original state.



Therefore one pulse is derived for every two applied.

This is the basis of a frequency divider circuit and may also be done with digital logic gates.

Oscillator frequency stability

Depends upon:

1. constant temperature,
2. constant voltages (interelectrode capacitances are then stable),
3. constant load,
4. loose coupling between oscillator and load,
5. no mechanical vibration,
6. component values being stable, with ageing also, (use air core coils in preference to those with magnetic cores which could be affected by temperature. Use air dielectric variable capacitors and polystyrene or silver mica fixed capacitors),
7. high C/L ratio in tank circuit (for high Q),
8. mounting coils away from metal objects and walls, (avoids capacity effects),
9. shielding from stray r.f., especially in transmitters,
10. high value of grid-leak resistance,
11. high anode voltage, low anode current,
12. FET or valve with high mutual conductance.

Motorboating oscillation

This is an unwanted oscillation that can occur in audio amplifiers and takes the form of a low frequency 'putt-putt-putt' sound similar to the sound of a motorboat! If the top d.c. 'supply' rail does not stay 'flat' it may provide a feedback path between stages of the same amplifier.

To eliminate this, including in battery operated equipment, capacitors must be fitted on the circuit board between the top supply rail and earth. These 'supply-decoupling' capacitors are normally electrolytic and about 100µF in value.

This capacitor will become charged, holding the rail at a constant 'flat' potential, and will also prevent possible distortion occuring during large variations of current such as with a Class B power amplifier.

Parasitic oscillations

Unwanted oscillations that can occur in any amplifier and have no relation to the signal intended to be amplified. Parasitic oscillations can be troublesome in transmitter r.f. power amplifiers. More about these in lesson 16.

Assignment 14.

1. Another name for positive feedback is -

   A. Decoupling.
   B. Regeneration.
   C. Rectification.
   D. Phase shift.

2. The advantage of a VFO over the crystal oscillator as a master oscillator is :

   A. Power supplies need not be thoroughly smoothed.
   B. The circuitry of the stage is simpler.
   C. Fewer stages of amplification are required for a given power output.
   D. It enables any frequency within the range of the V.F.O to be used.

3. If an oscillator stops when a small increase in load is applied the most likely cause would be -

   A. Insufficient positive feedback.
   B. Frequency shift causing neutralisation.
   C. Increased circuit "Q".
   D. Increased circulating current.

4. The operation of a tuned-anode, tuned-grid oscillator depends upon :

   A. The inter-electrode capacity of the valve.
   B. The grid-tuned circuit must be resonant at a slightly higher frequency than the anode-tuned circuit.
   C. A complete tuned circuit connected between cathode and earth.
   D. A small value capacitor connected from the anode to grid of the valve.

5. A suitably cut piezo-electric crystal can be made to oscillate at what is known as an overtone frequency. This overtone frequency is :

   A. An even harmonic of the fundamental frequency.
   B. Not influenced by temperature changes.
   C. An odd multiple of the fundamental frequency.
   D. Lower than the fundamental frequency.

6. To obtain a 125kHz calibration signal from a 1MHz frequency standard by digital division, which of the following could be used ?

   A. 1 divide by 2 flip-flop.
   B. 2 divide by 2 flip-flops.
   C. 3 divide by 2 flip-flops.
   D. 4 divide by 2 flip-flops.

7. Rigid mechanical construction of a VFO is desirable to minimise :

   A. A short term frequency instability.
   B. Long term frequency drift.
   C. Fracture of the crystal.
   D. Thermal frequency drift.

8. Which of the following would give most improvement to oscillator frequency stability?

   A. Use of coil formers with a high co-efficient of expansion.
   B. Tight thermal coupling between the oscillator and the final amplifier.
   C. Use of a well regulated power supply.
   D. Use of extensive RF shielding.

Questions 1, 3, 5, 6 and 8 in this assignment are reproduced from past examination papers courtesy of RFS.

Transmitter basics

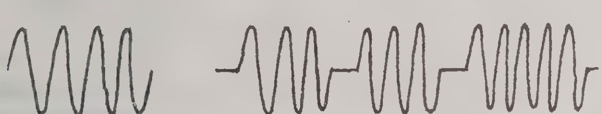
The transmitter

Equipment that generates r.f. oscillations which when connected to an aerial radiate these oscillations so they can be received at some other location.

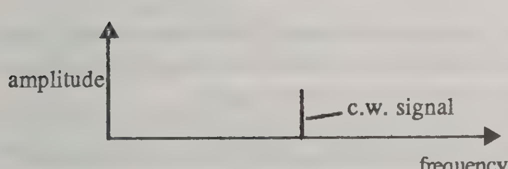
Modulation- the process whereby the r.f. oscillations are altered in some way to 'carry' intelligent information, such as morse code or speech.

Amplitude modulation systems

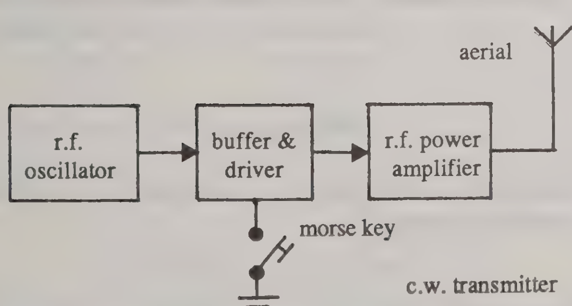
1. C.W. (A1A)- 'continuous-wave', carries no information unless 'keyed' on and off to represent the dits and dahs of the morse code.



r.f. waveform in relation to 'time'



r.f. waveform in relation to 'frequency'



c.w. transmitter

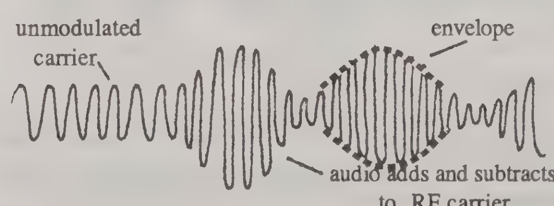
The r.f. oscillator can be crystal controlled or variable. The r.f. is fed to a 'buffer' stage which provides a light and constant load on the oscillator, so preventing subsequent keying from affecting oscillator stability. The key, when depressed, allows the signal to continue, normally by biasing the driver stage on.

The r.f. power amplifier increases the signal to the required power level and then feeds the aerial. The r.f. power amplifier may operate in the very efficient class C mode. Although the collector or anode current flows in relatively short bursts, the 'fly-wheel effect' of the tank circuit in this output stage will turn these back into a sine wave by releasing part of its energy during times of no current. This is just like the pendulum that swings back and forth in complete oscillations, even though it is pushed only once very briefly every cycle.

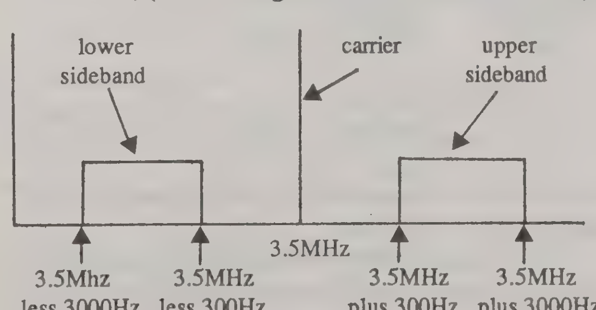
Advantages of c.w.-

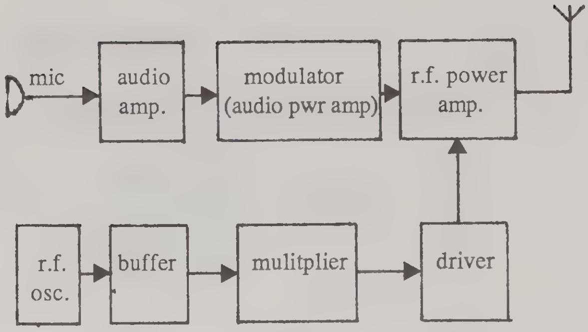
1. Requires only a simple transmitter,
2. narrow bandwidth (10Hz, easier to receive and takes up less space on band),
3. efficient class C power amplifier is used, ideal for small portable battery operated 'rigs'.

2. A.M. (A3E)- the r.f. wave, referred to as the carrier, is 'modulated' in amplitude by superimposing audio information onto it.



If the audio modulation varied in frequency from 300Hz to 3000Hz, (normal range for voice communications):





a.m. transmitter

Audio from the microphone is amplified and fed into the r.f. power amplifier.
The carrier originates in the r.f. oscillator, is 'multiplied' up to the desired frequency, amplified in the driver and the r.f. power amplifier. From here the combined 'modulated' signal is fed to the aerial.

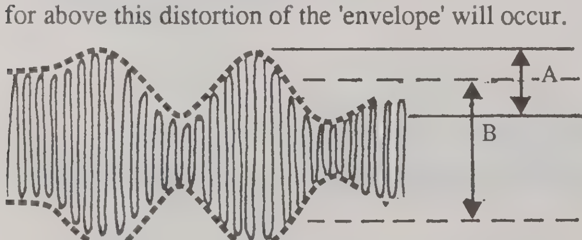
Multiplier- a 'non-linear' stage operating in class C that distorts a sine wave signal so as to produce lots of harmonics from that original signal. The mulitplier output will feed a tuned circuit which selects the desired frequency.

In this way the oscillator may for example operate not only for the 3.5MHz, 80-metre, amateur band, but multiplied up for operation on higher frequency bands such as 7MHz, 14MHz, and so on.

Modulation percentage- the amplitude of audio in relation to the carrier level and determines the shape of the waveform.

low modulation | 100% modulation | over modulation

For good reception it is desirable to make the modulation as high as possible, but less than 100%, for above this distortion of the 'envelope' will occur.



$$\text{MODULATION \%} = \frac{A}{B} \times \frac{100}{1}$$

To attain 100% modulation the audio power must be equal to half the r.f. power.

For example, with 100 watts of rf carrier, 50 watts of audio is required for 100% modulation. Total power will be the sum of these = 150 watts.

Aerial current in a.m. wave- if an unmodulated carrier is then modulated 100%, the current flowing out of the transmitter to the aerial will increase exactly 1.225 times.

$$P = I^2 . R$$

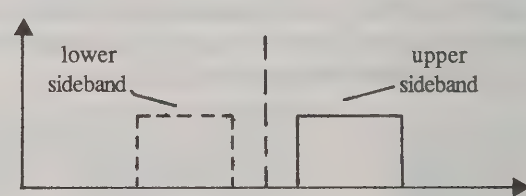
$$\text{therefore } I = \sqrt{\frac{P}{R}}$$

So, we can see I is proportional to $\sqrt{P}$

Therefore if P increases 1.5 times (for 100% modulation),

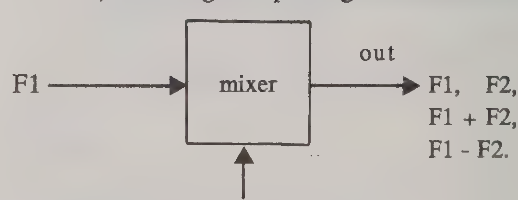
I will increase by $\sqrt{1.5}$ = <u>1.225 times</u>

3. SSB (J3E)- single sideband, the predominant type of modulation on h.f. amateur bands. In an a.m. signal, identical information is carried in each of the sidebands, therefore the carrier plus one of the sidebands can be eliminated and as a result give many advantages.



Mixer- converter, frequency translator: a 'non-linear' stage that will mix together two signals of different frequencies and produce at its output:

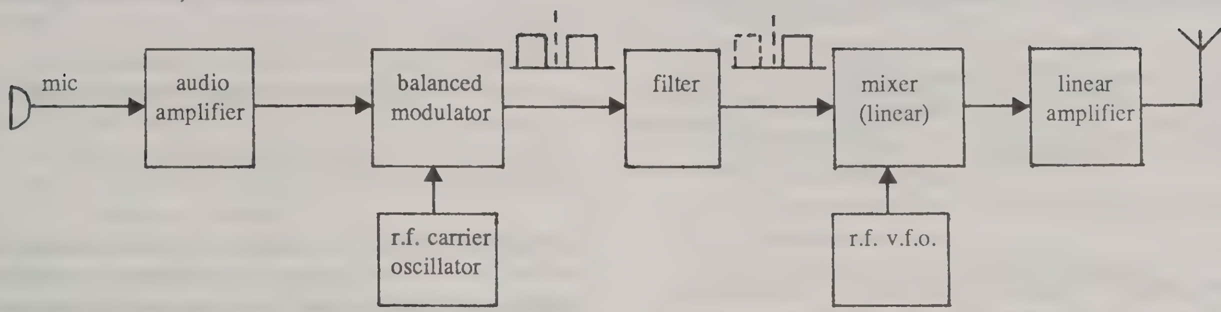
i) the two original signals,
ii) a new signal equalling the sum of the two,
iii) a new signal equalling the difference.



The output is fed through a tuned circuit to select the desired frequency.

Balanced modulator- balanced mixer, hetrodyne mixer, product detector, hetrodyne detector: a 'linear' stage that will mix together two signals of different frequencies and produce at its output only the sum and difference frequencies and not the input frequencies. (Some circuits though, do have one of the two input signals at the output).

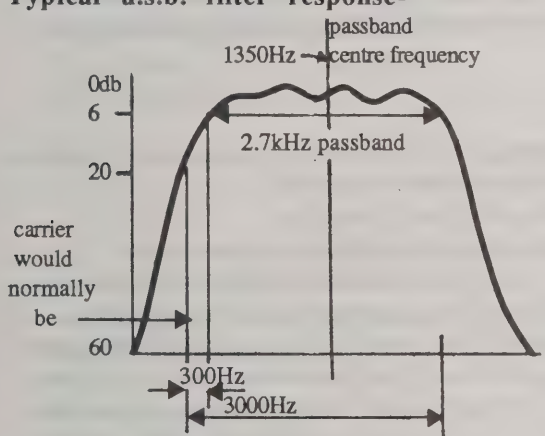
s.s.b. transmitter, filter method:



There are two principal methods of generating ssb-

a) The filter method- referring to the block diagram above, the audio and r.f. carrier are fed into a 'balanced-modulator', the output being an a.m. wave minus the carrier. This double sideband signal, (d.s.b.), is fed into a highly selective band-pass filter, passing only one of the sidebands. This 'single' sideband is 'mixed', (multipling will cause distortion), with a v.f.o. signal to change its frequency to a desired one. This is then amplified by a 'linear' r.f. power amplifier (no distortion).

Typical u.s.b. filter response-



b) Phasing method- below, the two d.s.b. signals from the balanced modulators are such that one sideband from each are in phase while the other ones are 180° out of phase and so 'cancel' out. The result is one 'single' sideband! The audio phase shift network is built to close tolerences to ensure the 90° phase shift holds constant over the audio range of 300Hz to 3000Hz.

SSB power- an ssb signal is a constantly changing value of r.f. Because of this the average power of the r.f. envelope during a modulation peak is used for transmitter rating, and is called 'peak-envelope-power', (p.e.p.).

(Average power in any sine wave, such as that found in a single r.f. cycle at the modulation peak, equals r.m.s. voltage times r.m.s. current. It is not usually called r.m.s. power).

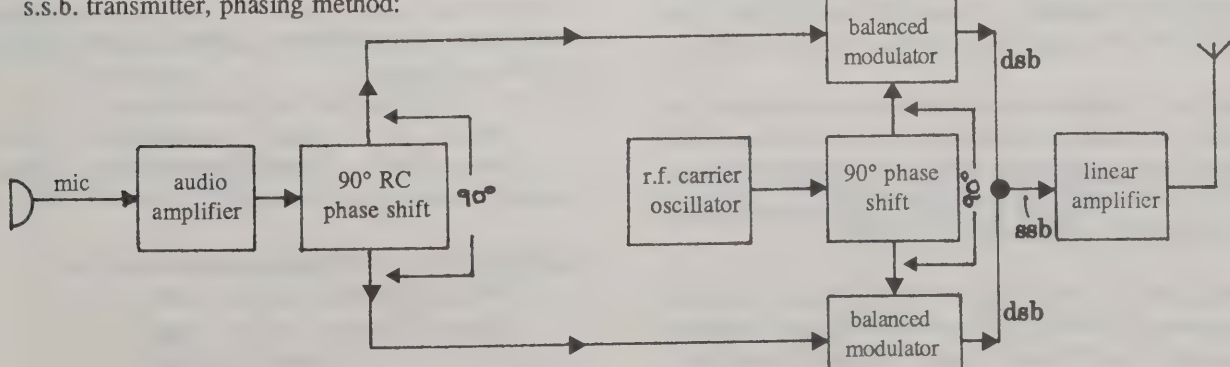
Advantages of ssb-

1. Uses less bandwidth
2. No transmitter power is wasted in a carrier that contains no useful information.
3. More intelligibility under severe adverse propagation conditions.
4. Effective power gain, a 100W p.e.p. ssb. transmitter will give equal performance to a 400W a.m. transmitter.
5. No carrier 'heterodyne' interference, (whistle caused by two close signals 'mixing' inside the receiver).

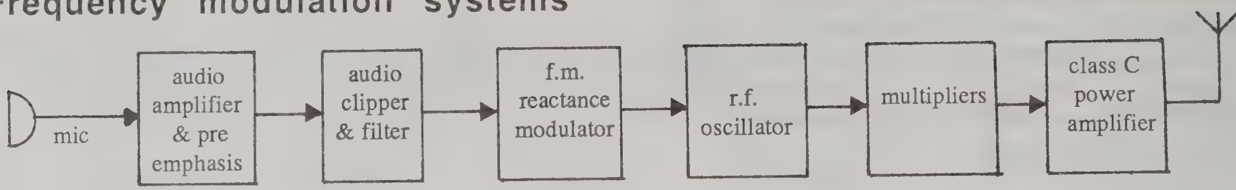
Disadvantages of ssb-

1. Stable transmitter and receiver oscillators are required. Permissible frequency variation is only 1% of that for a.m.
2. Filters of extreme selectivity are needed in the 'filter-method'.
3. Careful design of audio phase-shifter is required in the 'phase-method'.
4. Linear power amplifiers that are difficult to design are required.

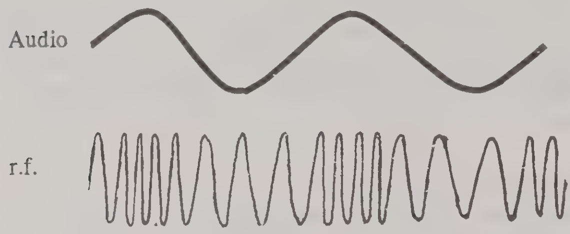
s.s.b. transmitter, phasing method:



Frequency modulation systems

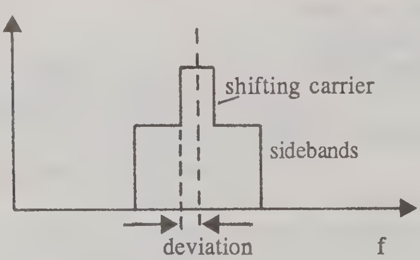


FM (F3E)- frequency modulation, predominant mode on v.h.f. The signals frequency is rapidly shifted back and forth under the influence of audio.



The higher the audio amplitude, the greater the 'deviation' of the r.f.

The frequency of the audio determines the 'rate' per second at which the deviation occurs.



FM sidebands- an f.m. signal produces several sidebands, the individual spacing of each being equal to the modulating frequency. These sidebands will affect the overall bandwidth of the signal.

In the block diagram- the microphone drives a low level audio amplifier with a 'pre-emphasis' network boosting higher audio frequencies. This creates an even spread of audio energy resulting in an f.m. signal of nearly constant energy distribution. The receiver will provide 'de-emphasis' to restore the audio while at the same time reduce annoying high audio frequency 'hiss'.

The audio clipper prevents the transmitter deviating too much, but introduces harmonics in the process which then have to be filtered out. The audio is next applied to a reactance modulator which varies the r.f. oscillator's frequency and so produce an f.m. signal.

This signal is 'multiplied' up to the desired operating frequency, (deviation is multiplied also), and then boosted by an efficient Class C r.f. power amplifier.

Modulation index- a measure of an f.m. signal that will reflect the amplitude of the sidebands as well as being directly proportional to the number of these sidebands, (giving also then, an indication of bandwidth).

$$\text{MODULATION INDEX} = \frac{\text{DEVIATION (freq. shift one dir)}}{\text{MODULATING FREQUENCY}}$$

PM (G3E)- phase modulation, indirect f.m., the phase of the carrier current is varied by the audio applied to the output of the r.f. oscillator. Deviation will increase now with both audio amplitude and frequency. The "modulation index" with p.m. will always work out to be constant regardless of modulating frequency.

Advantages of frequency modulation systems-

1. Noise interference is reduced,
2. high quality audio possible,
3. audio stages of only low power are required because modulation is carried out at a low level,
4. efficient Class C power amplifier can be used,
5. transmitter has small size for a given power output,
6. no carrier 'hetrodyne' interference because only the strongest signal will be heard on any particular frequency. Known as "capture effect".

Disadvantages of f.m. systems-

1. Wide bandwidth required,
2. Greater care needed in alignment.

Decibels (db's)

A 'logrithimic' scale, similar to the response of the human ear, for measuring power gain or loss in amplifiers and aerials.

Power x2 = +3db (power + 2 = -3db)
Power x10 = +10db (power + 10 = -10db)

<u>Example:</u> 5 watts to 100 watts expressed in db's-

5w to 50watts = x10 = +10db
50w to 100watts = x2 = <u>+3db</u>
∴ total = <u>+13db</u>

Assignment 15

1. A buffer stage is desirable between the oscillator and succeeding stages in a transmitter because -

   A. It acts as an active attenuator.
   B. It provides a means of compensating for frequency instability.
   C. It minimises reaction on the oscillator by the keyed or modulated stage.
   D. The output is not tuned to the same frequency as the input.

2. Two frequencies of 455 kHz and 1 kHz are fed into a balanced modulator in a SSB transmitter. The predominant frequencies present at the output will be -

   A. 1 kHz, 454 kHz and 456 kHz.
   B. 454 kHz and 456 kHz.
   C. 454 kHz, 455 kHz and 456 kHz.
   D. 455 kHz and 456 kHz.

3. The frequency of a single sideband signal may be satisfactorily changed using -

   A. A heterodyne mixer.
   B. A frequency multiplier.
   C. An untuned buffer.
   D. A harmonic amplifier.

4. The bandwidth of a filter type SSB transmitter is mainly dependent on :

   A. The adjustment of carrier suppression in the modulator.
   B. The adjustment of sideband balance in the modulator.
   C. The selectivity characteristic of the filter.
   D. The overall gain of the linear amplifier stages.

5. In a frequency modulated transmitter the amplitude of the carrier is :

   A. Inversely proportional to the frequency of the modulating signal.
   B. Proportional to the amplitude of the modulating signal.
   C. Proportional to the frequency of the modulating signal.
   D. Independant of the modulating signal.

6. The application of a 1000Hz tone to a frequency modulated system will result in -

   A. A single frequency displaced 1kHz from the carrier frequency.
   B. A shift of the centre frequency by 1000Hz.
   C. 2 frequencies, one 1kHz above the carrier and the other 1kHz below the carrier.
   D. A number of frequencies spread at 1kHz intervals each side of the carrier.

7. Frequency modulated transmitters usually use frequency multiplication rather than frequency translation for achieving an output on VHF or UHF. This is because -

   A. Frequency translation distorts an FM signal.
   B. Deviation increases with frequency multiplication.
   C. Frequency multipliers use crystals.
   D. Limiter stages can be inserted between multipliers.

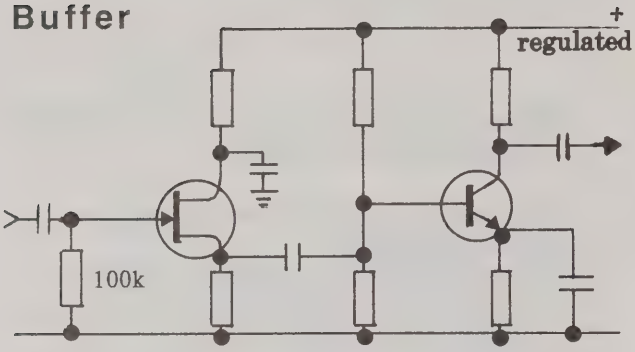
8. Expressed in decibels, a power gain of 4 is -

   A. 3 dB.
   B. 4 dB.
   C. 6 dB.
   D. 8 dB.

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Transmitter details

Buffer

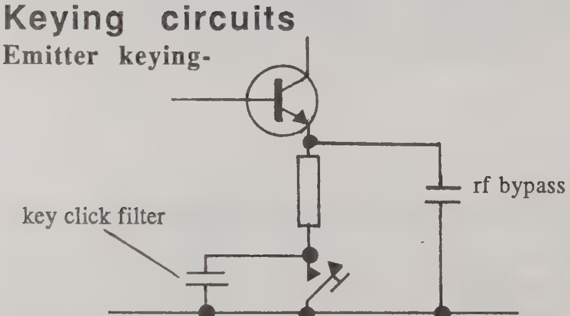


A junction FET, with its high input impedance, presents a light and constant load to the oscillator. Being a source follower stage, it offers no voltage gain but, provides a good degree of isolation between the input and what happens after the output. This buffer includes a second stage to provide some amplification.

The output circuits of each stage are not tuned, to avoid any chance of resonance effects feeding back to the buffer input causing problems with oscillator stability.

Keying circuits

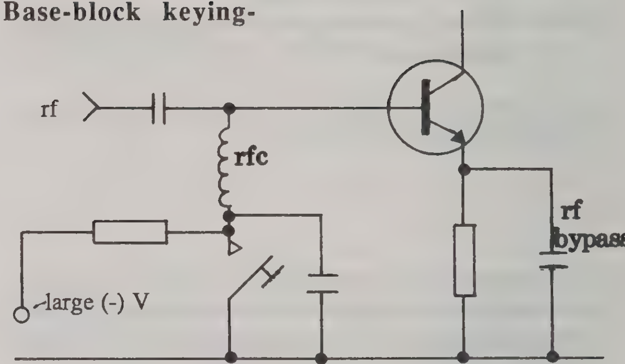
Emitter keying-



Usually in a driver stage. The morse key is depressed, base-emitter current flows, and the stage amplifies normally, allowing the r.f. oscillations to continue onto the next stage. When the key is 'up' no bias or collector currents flow so there will be no output.

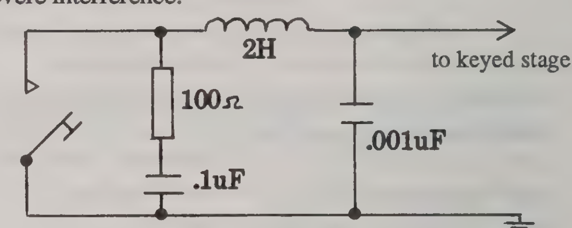
Because the key switches on and off very quickly, the bursts of r.f. at the output will approach that of a 'squarewave' containing many harmonics. With any keying method these will produce sidebands either side of the carrier and cause interference sounding like 'clicks'. The "key click filter" will eliminate this interference by 'rounding-off' the keyed waveform.

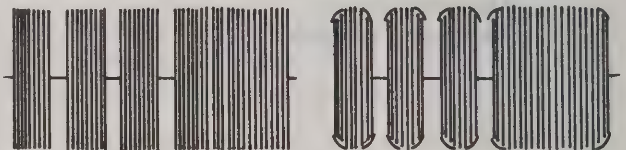
Base-block keying-



The transistor is biased off by a high negative voltage until the key is depressed, which then very effectively removes this reverse bias.

Key click filter- a more sophisticated approach for severe interference.





with no filter at all   with key click filter

Chirp- frequency instability each time the transmitter is keyed and causes a change in 'tone' from beginning to end of each character. It may be caused by:

a) **d.c. instability** where the r.f. oscillator is fed with d.c. from the same point as subsequent stages,

b) **pulling** where the buffer stage is not providing enough isolation,

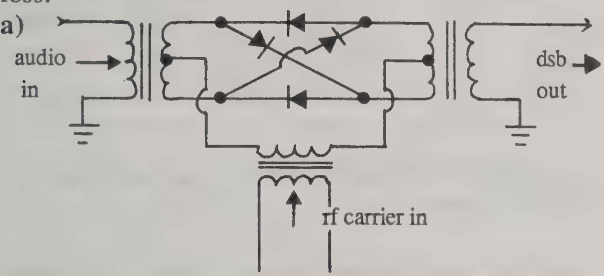
c) **r.f. feedback** where the signal from a high level stage leaks back to the oscillator.

Balanced modulator

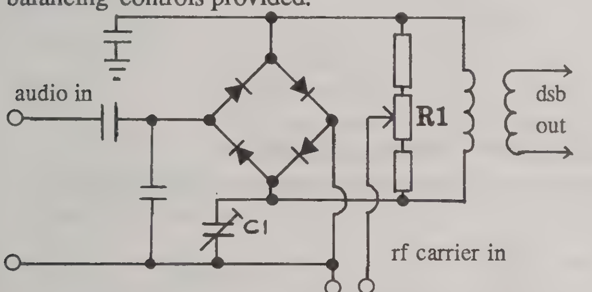
A 'linear' mixer to eliminate the carrier, leaving a dsb.

1. Passive, ring types- causes a small 'insertion' loss.

a)

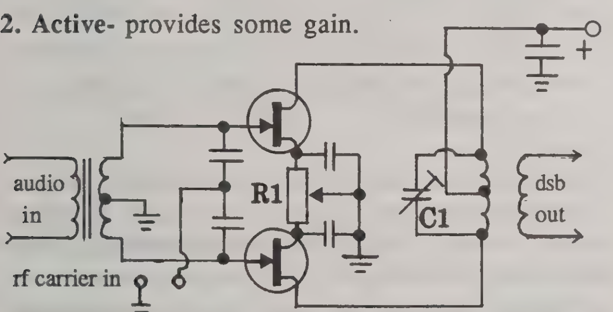


b) a variation on the circuit above but with two 'balancing' controls provided.



R1 and C1 are adjusted for minimum carrier output.

2. Active- provides some gain.

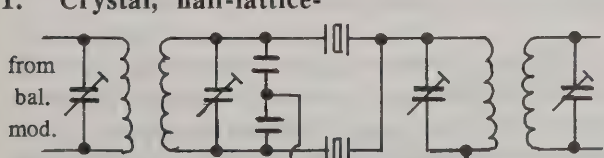


A push-pull amplifier, although no audio appears at the output because the tuned circuit is adjusted, (with C1), to what would be the 'carrier' frequency. The carrier 'cancels-out' because its fed to each gate 'in-phase'. R1 provides adjustment for maximum carrier suppression.

Bandpass filters

To pass one sideband in the ssb filter method.

1. Crystal, half-lattice-



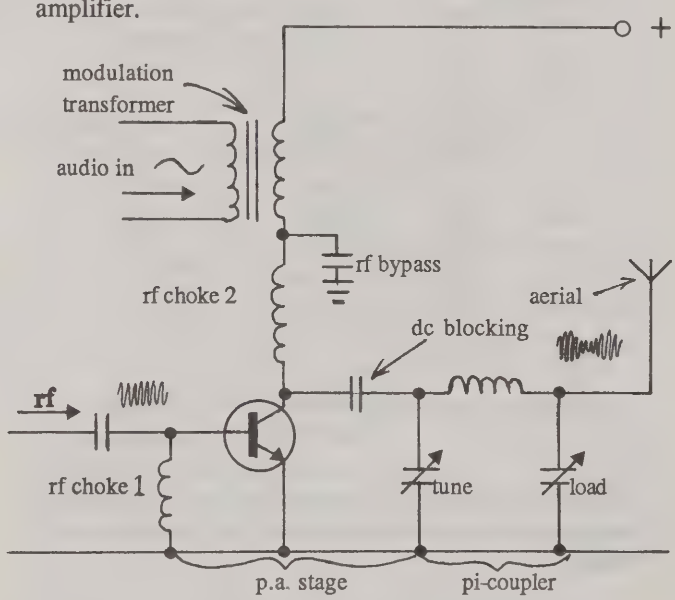
Two crystals with series resonant frequencies that differ by an amount equal to the bandwidth required, usually 2.7 kHz. Used up to 30MHz.

2. Mechanical- a set of small round discs which physically vibrate at a particular frequency due to special transducers. Simulates a series tuned circuit. Their characteristic is of a flat top and steep sides, (skirt). Available 60 to 600KHz.

3. Ceramic- small discs of ceramics vibrate due to 'piezoelectric' effect, similar to crystals. Used up to 10.7MHz.

AM modulation

Normally carried out at the final power amplifier stage of the transmitter to avoid the need for a linear power amplifier.



r.f. power amplifier

The power amplifier operates in class C with r.f. choke 1 providing a path for the base-emitter bias current. (Refer page 11.4).

Audio is fed into the "modulation transformer" causing the transistors collector voltage to rise and fall in sympathy with this audio. The overall r.f. output of the transistor will now vary in amplitude, also in sympathy with the same audio. We now have amplitude modulation!

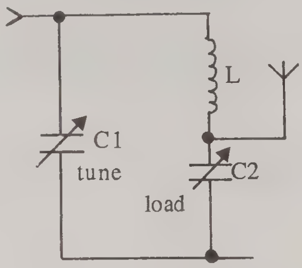
R.F. choke 2 and the r.f. bypass capacitor prevent r.f. from reaching the audio stages or power supply but has no effect on the lower frequency audio variations.

The new a.m. signal is fed into a "pi-coupler", (see next page), and delivered to an aerial.

The pi-coupler

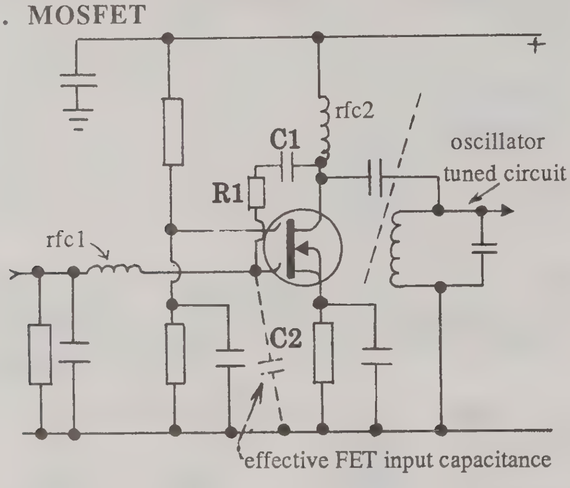
A resonant tuned circuit whose output impedance is able to be adjusted over a wide range. It can be used for all types of transmitters, not just a.m., and because of its resemblance to a low pass filter, is very good at reducing unwanted harmonics.

Both capacitors will affect the resonant frequency although mainly C1. C2 will provide matching and so determine the optimum transfer of power into the aerial.



FM reactance modulators

1. MOSFET



The audio varies the r.f. carrier frequency by causing a varying reactance to appear across the oscillators tank circuit.

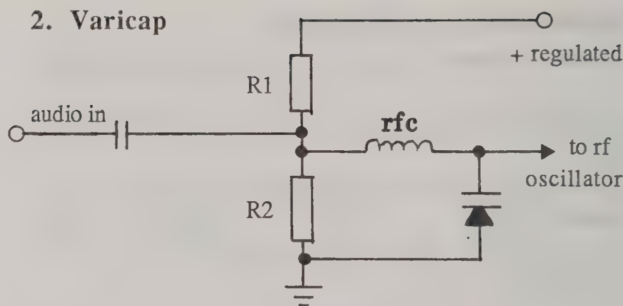
i) R1 is large compared to the reactance of C1 and C2. Therefore the rf current through C1, R1, C2 is in phase with the rf voltage across them all, which is also across the oscillator's tuned circuit. (Resistor in an a.c circuit, page 7.3).

ii) The voltage across C2 (MOSFET input) will lag the current by 90° (C I V I L).

iii) The voltage across the oscillator tuned circuit (MOSFET output) will be 180° out of phase with the input and now lead that current by 90° (C I V I L). This is inductive.

The audio is producing a varying inductive reactance that varies the r.f. oscillator's frequency. We now have 'frequency modulation'!
RFC 1 prevents r.f. from feeding back into the audio stages while rfc 2 provides a 'load' for the MOSFET.

2. Varicap

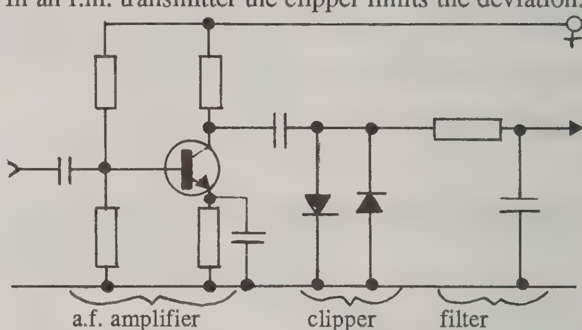


The variable capacitance diode is reversed biased by voltage divider R1 and R2.

Audio is superimposed on this bias. The diodes capacitance varies and, being connected to the r.f. oscillator, so causes the oscillators frequency to vary.

Clipper and filter

In an f.m. transmitter the clipper limits the deviation.



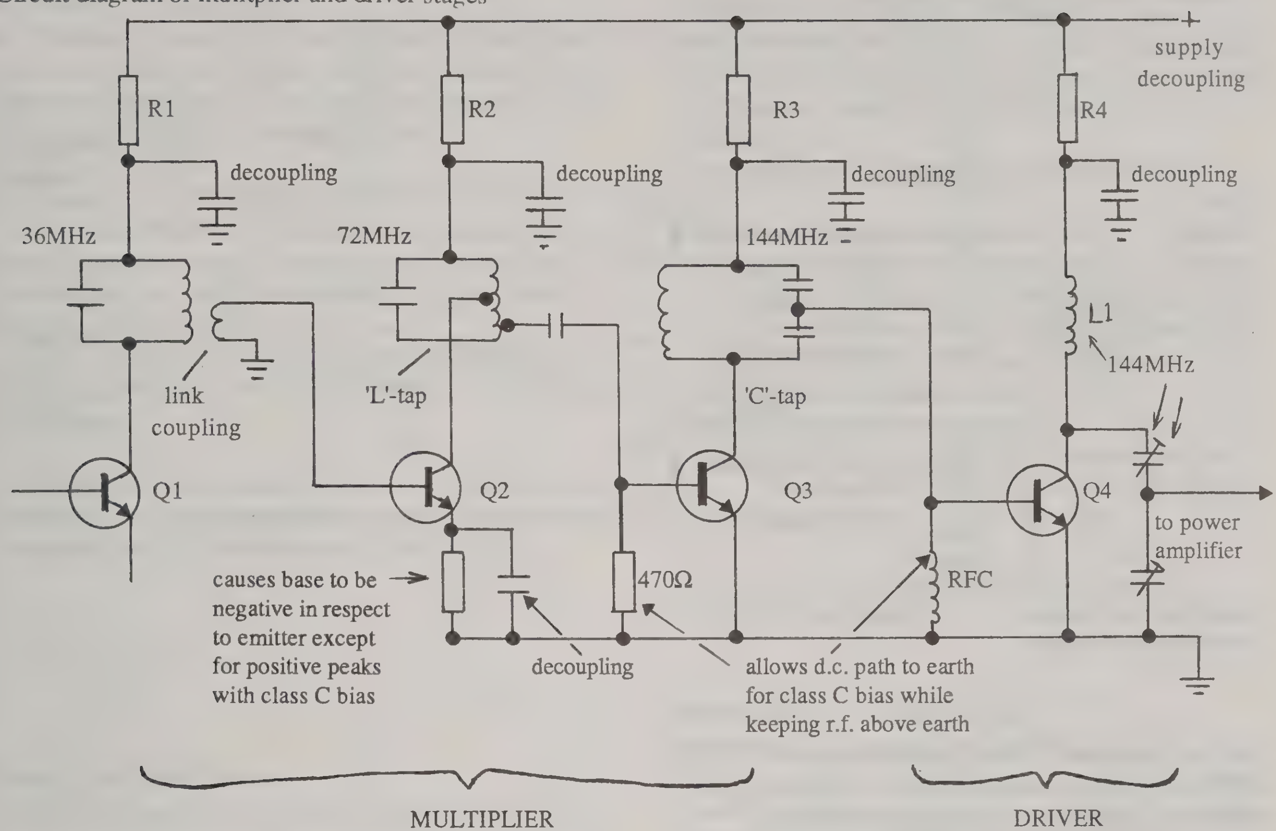
Two back-to-back diodes conduct above their junction barrier potential and so prevent the audio waveform going above 0.7v when using silicon diodes, (0.3v for germanium). The low pass filter helps to eliminate the harmonics created by this harsh clipping process and so reduce the distortion caused.

RF multipliers and driver

Refer to the top diagram on the next page. The class C mulitplier stages create distortion and so produce lots of harmonics. A tuned circuit in each collector 'selects' the wanted frequency. Q1 is tuned to, say, a third harmonic of a 12MHz oscillator signal. Q2 doubles this to 72MHz, and is doubled again by Q3 to 144MHz.

The coupling between stages transfers energy but must 'match' impedances to ensure maximum power is transferred. Three types of coupling are shown.
The driver operates in class C, but this time for reasons of efficiency, not multiplication. (Flywheel effect of tuned circuit ensures sine wave output- page 15.1). A reasonable amount of gain is available from this stage.

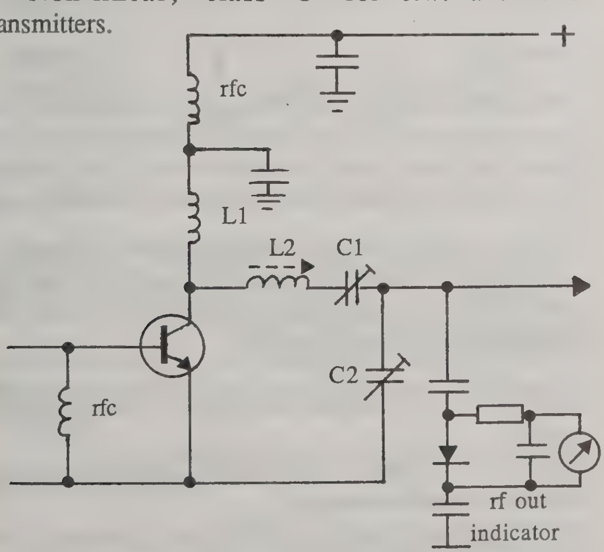
Circuit diagram of mulitplier and driver stages



R1 to R4 provide the correct d.c. collector voltage for each transistor and enables the calculation of stage currents by connecting a voltmeter across them.

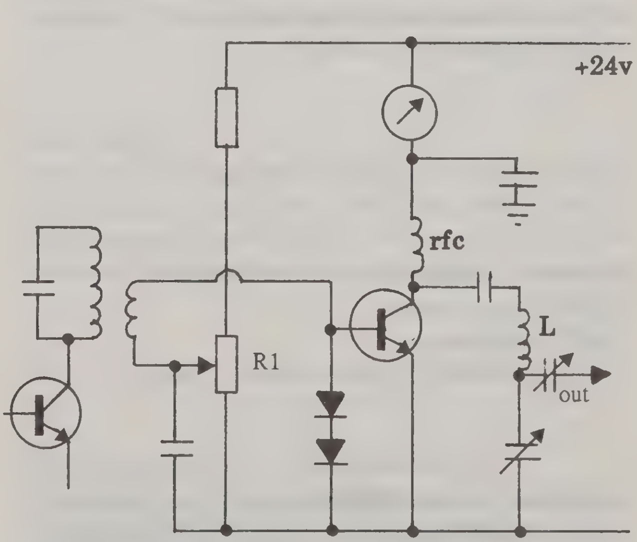
RF power amplifiers

1. Non-linear, class C- for c.w. and f.m. transmitters.



L2, C1 and C2 form a tuning network and are in such a configuration as to provide a correct match up to the load impedance. They are adjusted for maximum r.f. output.

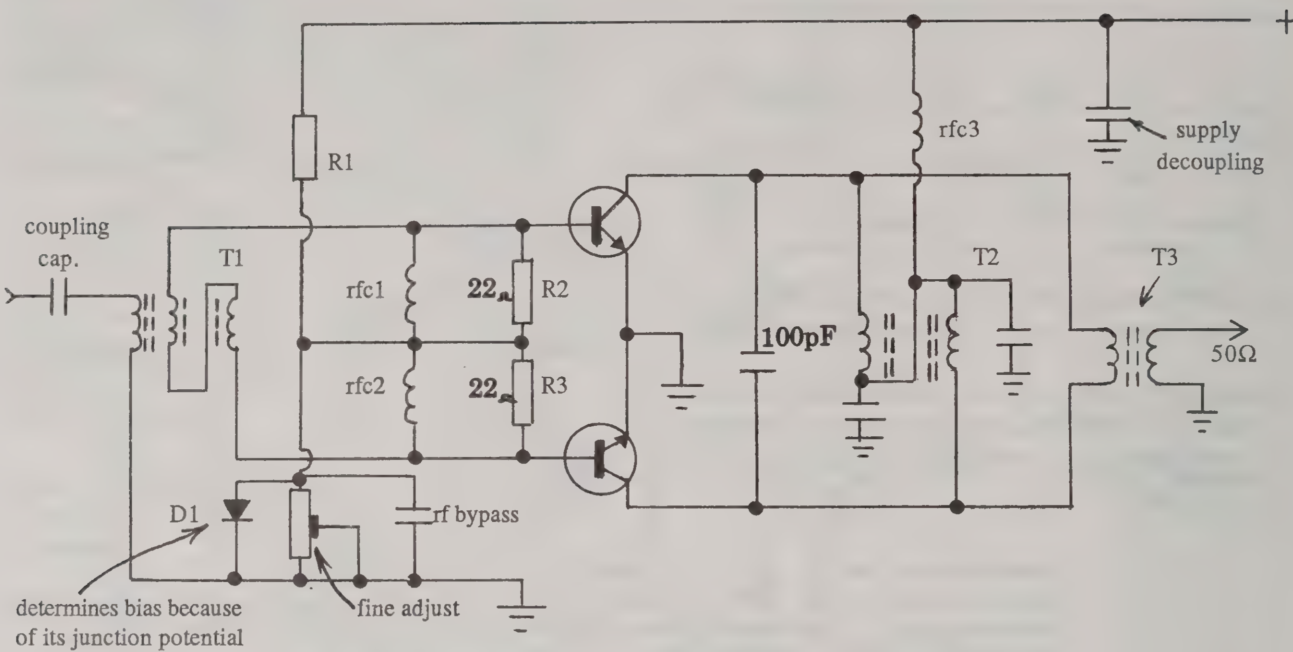
2. Linear, class A- for a.m. and ssb.



For low power levels up to about 10 watts.

The bias is adjusted with R1 to give a standing collector current of 50mA. The two silicon diodes prevents the bias from rising too high, either from adjustment or by the signal, and so prevents damage to the transistor.

3. **Linear, class B-** for a.m. and ssb.



This is a 'broadband' circuit, with transformers T1, T2 and T3, all wound on toroid cores, (refer page 8.4), eliminating the usual large tuning components.

The bias is determined by voltage divider R1 and D1 with some fine adjustment provided by the trimmer. D1's forward voltage drop will conveniently set the base of the transistors, via rfc1 and rfc2, at their junction barrier potential, (just near the point of conduction).

R2 and R3 will prevent any unwanted resonances. The collector supply is derived via rfc3 and T2. T2 also recombines the two class B waveforms. T3 transforms the low collector output impedance up to 50 ohms to match the load such as an aerial.

Power amplifier ratings

1. DC input power

DC POWER input =

E supply x I collector/anode. watts

2. Output stage efficiency

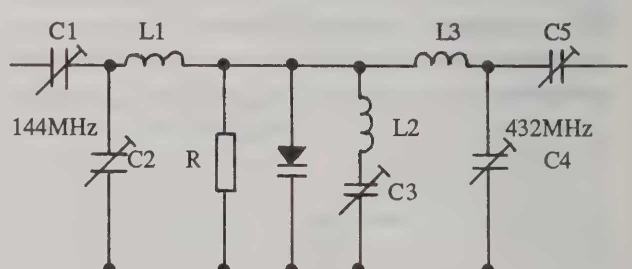
$$\% \text{ EFFICIENCY} = \frac{100 \times \text{RF POWER load}}{\text{DC POWER input}}$$

3. Collector/anode dissipation

DISSIPATION = DC POWER input - RF POWER load

Power frequency multiplier

Variable capacitance diodes, (refer page 9.3), can be used as frequency multipliers. This is because of their non-linear junction capacitance which can generate considerable harmonic energy.



This is a tripler circuit providing about 9 watts of output with 15 watts in. Both c.w. and f.m. may be used. With a.m. care must be taken to ensure the modulation does not exceed 80%.

C1, C2, L1 is matched and tuned to the 144MHz source.
L2, C3 is a series tuned circuit 'shorting-out' the 288MHz second harmonic.
C4, C5, L3 are tuned to 432MHz and matched to the load.

R determines the reverse bias voltage to be developed across the diode by the signal. No separate bias voltage is provided.

Tuned circuits

1. Lumped circuit- those separate coil and capacitors we are familar with and used up to approximately 200MHz. Above this the efficiency falls off and the following types must be used.

2. Linear circuit, tuned line.

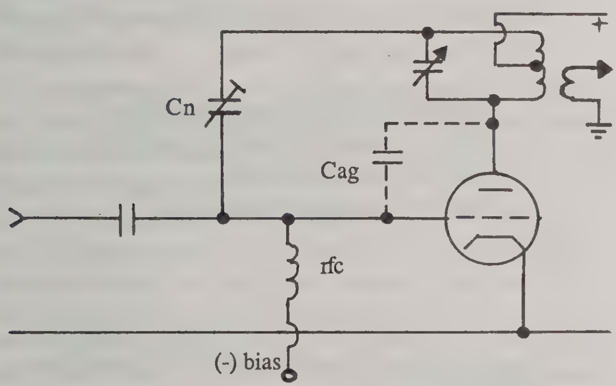
a) Stripline- a transmission line resonator, made from flat copper or brass strips, quarter of a wavelength, (or multiples thereof), long and used in v.h.f./u.h.f. tank circuits.

b) Microstrip line- also a transmission line resonator, but etched into a double sided printed circuit board.

3. Cavities and trough lines- a single inner conductor running length-ways inside a cavity or rectangular trough. Used frequently above 400MHz.

Neutralisation

This is required to prevent self-oscillation due to the feedback of energy via the valves anode-grid capacitance.



Cn provides a feedback path that is equal in amplitude, but in the opposite phase, to the feedback going through Cag. The two feedback paths therefore cancel out. Applicable also to FET and transistor circuits.

Adjustment procedures- carry out at the highest frequency the amplifier is to be used. Two methods:

1. Cold Method- anode voltage removed, load disconnected, Cn adjusted to a point where adjusting the anode tuning capacitor does not affect the grid current.

2. Hot Method- similar to above but with anode voltage applied.

To check if the correct neutralisation adjustment has been made: reduce anode voltage, remove grid drive, adjust bias to give half the maximum permissible anode dissipation. Self-oscillation should not occur and an r.f. indicator, (a small bulb connected to a loop of wire), held near the 'tank' circuit will verify this.

Parasitic oscillations

These unwanted oscillations are caused by resonances which exist in either the input or output circuits and can occur above or below the operating frequency.

Eliminate by-

1. Use short base/grid leads, longer collector/anode leads,
2. leads should be large diameter,
3. use dissimilar chokes in base/grid and collector/anode circuits, OR, fit resistors, 10 - 22Ω, in base or collector circuit as close as is practical to the transistor. (Likewise, resistors 47 - 100Ω in grid or anode circuits).
4. fit ferrite beads on transistor leads,
5. use two bypass capacitors with transistors, one for operating frequency, other for low frequency,
6. use beam tetrodes and pentodes.

Harmonic reduction

1. Use bandpass couplers between stages, especially high power transmitters,
2. avoid capacity coupling between driver and p.a. stage,
3. a push-pull stage eliminates even harmonics,
4. design the tank circuit to have a high 'Q',
5. use a pi-network tank circuit,
6. use electrostatic shield or Faraday screen between tank coil and output coupling coil to ensure pure inductive coupling,
7. use add on low-pass filter in the aerial lead,
8. build the transmitter in an earthed metal cabinet,
9. fit r.f. filters in all power and control leads.

Tuning

In a typical h.f. transmitter the 'drive' control is adjusted for maximum grid drive. The 'tune' control, in the collector/anode tank circuit, is adjusted for a dip in collector/anode current, (maximum output).

SSB speech processing

Compression- limiting, brings the low and higher audio levels closer together to raise the overall average power. The degree of compression is sometimes switchable and can improve reception of poor signals.

ALC- automatic level control, maintains the peak rf output at a relatively constant level, just below the point at which the final amplifier could be over-driven.

Assignment 16

1. Interference caused by keying a radiotelegraph transmitter may be considerably reduced or eliminated by :

   A. Increasing the drive to the final power amplifier stage.
   B. Shielding the RF power amplifier.
   C. Shaping the RF waveform at the keyed stage(s).
   D. Reducing the loading on the final amplifier stage.

2. Generation of a frequency modulated signal can be achieved using a :

   A. Frequency discriminator.
   B. Reactance modulator.
   C. Low level amplitude modulator.
   D. Balanced modulator.

3. When neutralising a triode RF power amplifier an RF indicator coupled to the plate tuned circuit can be used to determine the correct neutralising adjustment. Using this method it is necessary -

   A. To connect a bypass capacitor from grid to plate.
   B. To connect a bypass capacitor from grid to cathode.
   C. To remove the grid drive.
   D. To remove the anode voltage.

4. If a correctly-matched antenna becomes detached from a transmitter during operation -

   A. The final amplifier valve grid current will rise to a high value.
   B. The final amplifier valve plate dissipation rating may be exceeded.
   C. The grid drive to the final amplifier valve will fall to zero.
   D. The final amplifier valve plate current will fall to zero.

5. Parasitic oscillations occurring in radio frequency power amplifiers -

   A. Are due to a negative feedback path existing between the input and output circuits.
   B. Can occur at VHF as well as lower frequencies.
   C. Have insufficient level to be radiated by the antenna.
   D. Can be reduced by increasing the supply voltage.

6. Harmonics are generated by a transmitter when-

   A. High power amplifiers are employed.
   B. Non-linearity occurs in an amplifier stage.
   C. High "Q" tank coils are employed in amplifier stages.
   D. The power amplifier stage is operated in Class A.

7. When the tank circuit of a correctly operated final amplifier is tuned through resonance the aerial current will -

   A. Increase as the capacitance decreases.
   B. Fall to a minimum then rise again.
   C. Show no variation at all.
   D. Rise to a maximum then fall.

8. Automatic level control (a.l.c.) is included in an SSB transmitter to -

   A. Control the level of carrier balance.
   B. Minimise the possibility of modulation peaks over-driving the final amplifier.
   C. To increase the peak envelope power in the transmitted signal.
   D. Reduce output stage dissipation during no modulation.

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Collect an examination application form. Fill it in, and send it off within the next couple of weeks.

LESSON 17

Receiver basics

The receiver

Equipment to convert r.f. waves into audible signals. A receiver must have an:

1. aerial- to intercept radio wave signals,

2. tuned circuit- to select the frequency of the signal.

3. detector- to 'de-modulate' the signal and obtain the audio information from it.

4. transducer- to enable the audio signal to be heard by the human ear.

Receiver specifications

1. Sensitivity- the ability of the receiver to respond to small signal voltages above the internal noise generated within the receiver. Sensitivity may be described in terms of:

a) Signal-to-Noise ratio- the ratio, of audio power output, of a received signal, (including any receiver noise), to that of no signal, (receiver noise only). Used for c.w., a.m., and ssb.

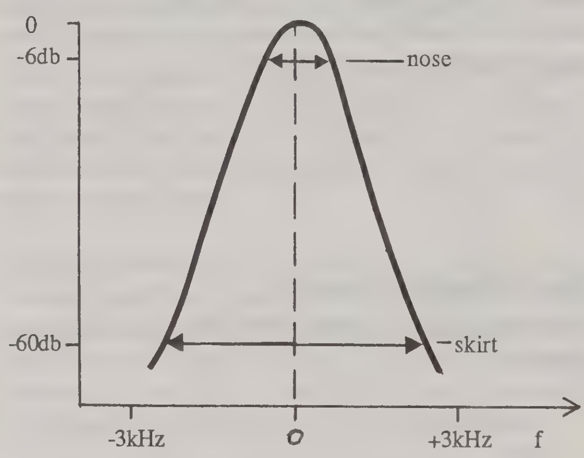
For example, a receiver with a bandwidth of 2.7kHz and an input signal of 0.5µV may have a signal-to-noise (S+N/N) ratio of 10db. In any receiver, the narrower the bandwidth the better the S+N/N ratio.

b) noise factor- is independant of bandwidth and expressed in db's. For example, a receiver may have a noise factor of 10db. A smaller figure would indicate a more sensitive receiver.

c) quieting- for f.m. receivers, which have a loud 'hiss' under no signal conditions. This quietens down when a signal is received. An f.m. receiver may have, say, a sensitivity of 0.4µV for 20db quieting.

2. Dynamic range- the range between the weakest detectable signal, and the strongest signal that can enter a receiver before it affects the reception of a wanted station. The dynamic range is given in db's, with typical figures of 85db or more for good receivers. It is harder to design a transistorised receiver of good dynamic range than it is for a valve one. One way to improve 'strong-signal performance' and prevent 'overloading' is with an "r.f. attenuator" at the receiver input.

3. Selectivity- the ability of a receiver to discriminate against signals adjacent to the wanted frequency. (Adjacent channel interference). This will depend upon the bandwidth or 'passband' of the receiver and is quoted using two measurements taken on this passband curve. One is at the 'nose' and the other is on the 'skirt'.



For example a receiver may have a selectivity of 2.7kHz at -6db and 4.9kHz at -60db. The ratio of these measurements is known as the 'shape factor' and in this example would be just over 1.8.

4. Stability- the ability to 'stay-put' or tuned to a signal and is very important with ssb or, in fact, any receiver having a 'narrow' bandwidth. Most 'drift' occurs within the first ten minutes after switch-on. A receiver may be quoted as drifting no more than 200Hz in any 30 minute period after a 10 minute warm-up.

5. Fidelity- the sound quality as free of distortion as possible.

Desirable features

A.G.C.- automatic gain control, or automatic volume control, (AVC). A means of reducing receiver gain on strong signal levels, avoiding overloading and distortion, and also giving a relatively constant audio output.

Noise Limiter- to eliminate 'pulse' type noise such as ignition interference.

B.F.O.- beat frequency oscillator;

i) to enable ssb reception by 're-inserting' the missing carrier in the received signal and so allowing normal a.m. detection, and,

ii) to enable c.w. reception by 'beating' with the signal to produce an audible tone.

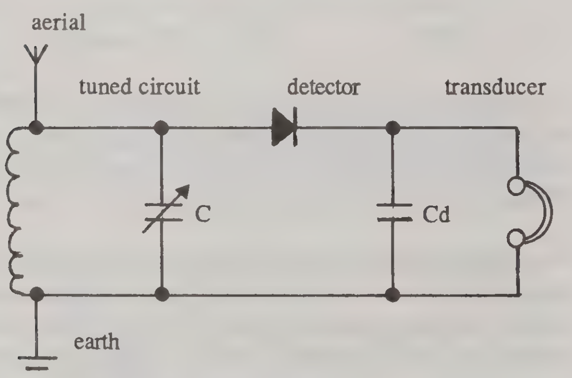
Squelch or mute- this allows the receiver to be left turned on when monitoring a desired frequency, but without any annoying background noise. When a station transmits on the frequency, the mute is over-ridden and is heard. Used extensively on v.h.f. receivers.

Signal strength meter- for indication of relative signal strengths.

Accurate calibration- of the frequency to which the receiver is tuned, and also precise movement of the tuning control with no 'backlash'.

The crystal set

For receiving a.m. signals. Poor sensitivity and poor selectivity.



rf across tuned tuned circuit

rectified signal without Cd

resultant audio with Cd

The aerial intercepts radio signals of many frequencies and, together with the earth, delivers them to the parallel tuned circuit. But, the tuned circuit will develop across it only a signal that is equal in frequency to its own resonant frequency. (Parallel tuned circuit- high Z). This resonant frequency can be changed with C, allowing an r.f. signal of a different frequency to be 'selected'.

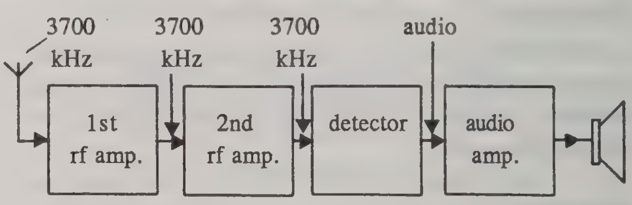
The tuned signal is rectified by a germanium point contact diode, and then applied across capacitor Cd. This capacitor behaves like a reservoir and charges up to the peak value of r.f., (but is not too large a value to stop the charge from rising up and down with the amplitude variations of the rectified signal).

The resultant waveform is identical to the original audio modulation and can be heard when fed into high impedance headphones.

The diode and capacitor Cd together form the detector which 'demodulates' the r.f. signal. Selectivity can be improved by 'tapping' the aerial and also the diode onto a lower winding of the coil. This will have the effect of raising the 'Q' of the tuned circuit.

The TRF

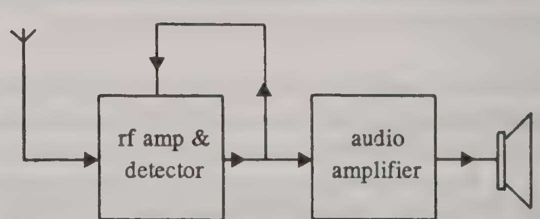
Tuned-radio-frequency receiver- for a.m., once popular. Several stages of tuneable rf amplification improve sensitivity and selectivity over the crystal set. Difficult to tune when there are many r.f. stages.



An audio amplifier enables a loudspeaker to be used.

The regenerative receiver

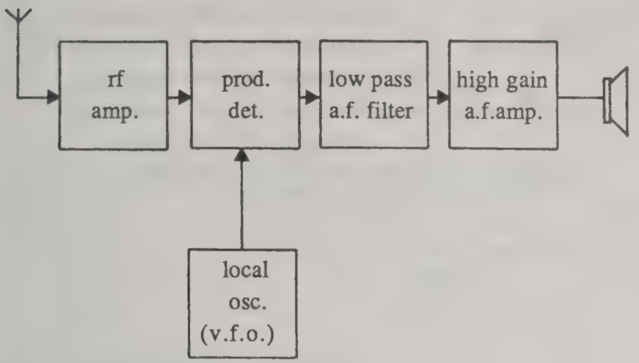
Good sensitivity due to some positive feedback, useful a.m. or c.w., poor selectivity in the presence of strong signals.



The positive feedback has to be carefully adjusted to a point just before oscillation begins. Interference may be caused to other receivers on the same frequency.

The direct conversion receiver

Synchrodyne or homodyne, for c.w. & ssb. Good sensitivity and selectivity. Good stability up to about 14MHz if care is taken in construction.



A signal from the r.f. amplifier is 'mixed' in the product detector with the output of a very stable 'local oscillator', (v.f.o.). The local oscillator is tuned to the signal frequency, (or only an audio beat away from it). This produces a 'difference' frequency and will be audio.

The product detector is a 'linear' mixer, (page 15.2), with an audio output. A 'linear' mixer enables the use of simple and inexpensive audio filters to provide extremely good selectivity.

A high gain audio amplifier is needed, especially for weaker signals, to make up for the lack of gain in the mixer stage. Tuning is carried out with the local oscillator and is carefully adjusted for the most 'natural' sound. If need be, a.m. can be resolved by tuning the signal in at 'zero-beat'.

The superhetrodyne receiver

Superhet, the most common receiver used today. High sensitivity, high selectivity, a.m., c.w., ssb, or f.m.

The signal on 3700kHz is amplified and fed into a tuneable mixer. The 'local oscillator', (v.f.o.), is adjusted to 4155kHz and also fed to the mixer. A difference or 'intermediate' frequency of 455kHz results, and is fed into an Intermediate Frequency (I.F.), amplifier of fixed frequency and high gain.

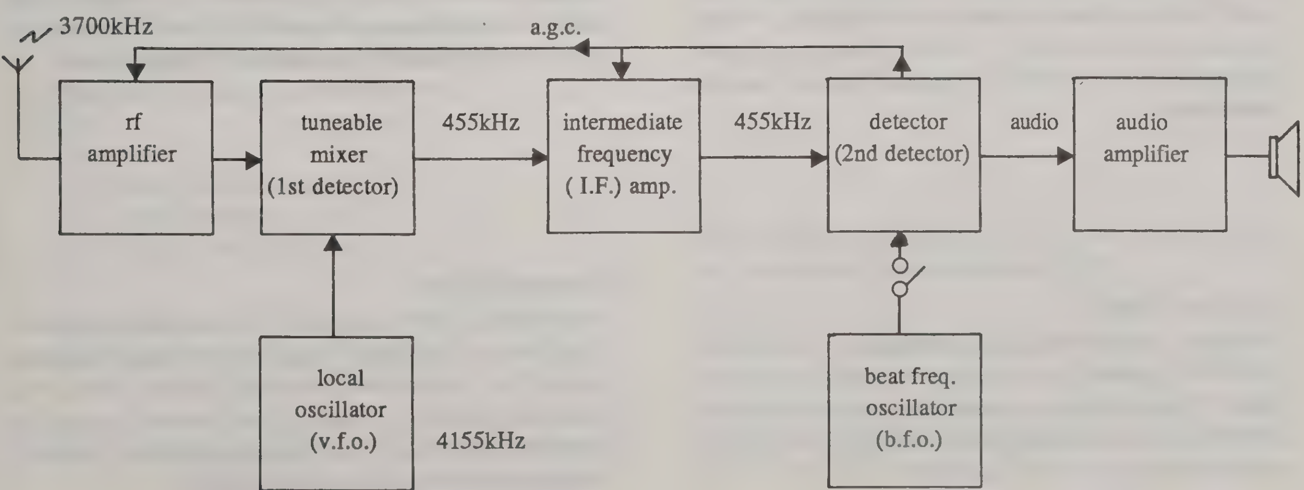
To ensure the signal always comes out of the mixer at the 455kHz I.F. the local oscillator frequency is changed each time a different r.f. frequency is tuned. This is done by using 'ganged' variable capacitors so that the three tuned circuits, (in r.f., mixer, and oscillator stages), are all able to be adjusted with only one tuning knob.

The 455kHz signal is detected in the usual way with a diode and then the audio amplified. The b.f.o. is switched in for ssb or c.w. signals, the frequency of which can be varied slightly with its 'pitch' control for the most natural sound.

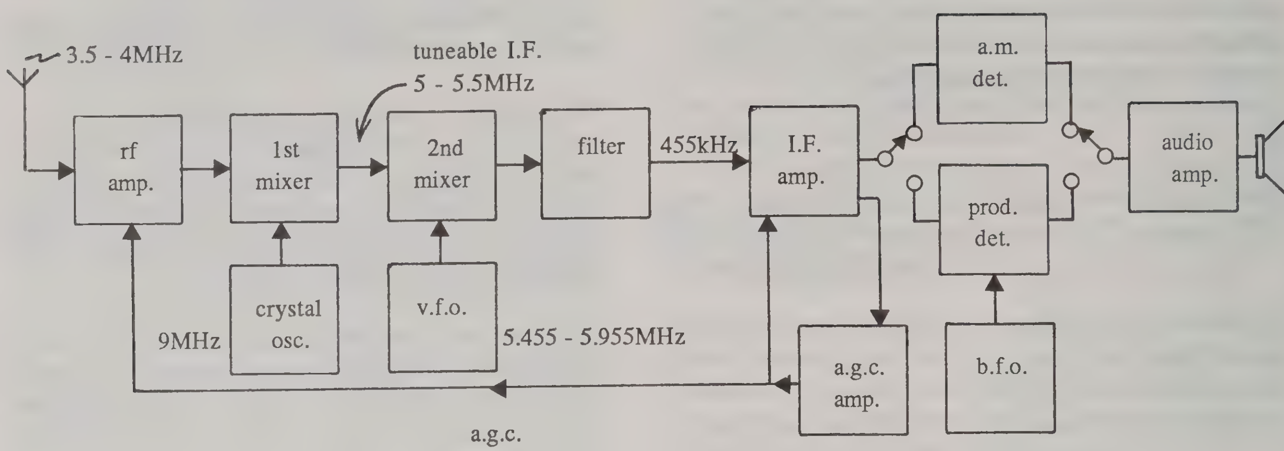
Double conversion, (top of the next page), is used in better receivers. It has two different intermediate frequencies. The first is higher, (tuneable 5.0 to 5.5MHz), than the second one, (455kHz). To cover other bands different crystals in the crystal oscillator are switched in. The filter determines the selectivity of the receiver.

The f.m. superhet, also on the next page, is a single conversion type with an I.F. of 10.7MHz. The a.f.c, automatic frequency control, stops the receiver drifting off frequency by monitoring the received signal and correcting the local oscillator frequency. Particularly useful at v.h.f. and above. A wideband I.F. is needed because of the signal's frequency deviations. The limiter removes any amplitude variations in the signal, such as noise, before it is demodulated by a f.m. detector.

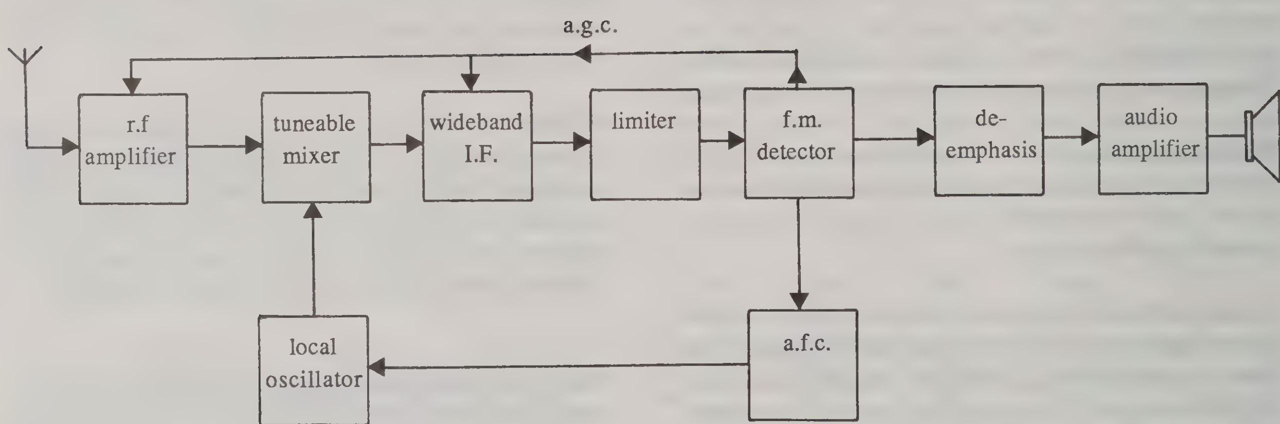
Single conversion superhet for c.w., a.m., and ssb.



Double conversion superhet for c.w., a.m., and ssb.



Superhet for f.m.



Transceivers

Equipment that combines both transmitter and receiver, utilising several common circuits. The microphone has a PTT, (press-to-talk), switch to enable transmission. Some transceivers also incorporate VOX, (voice-operated-switch), which allows automatic transmission whenever the operator speaks into the microphone.

Transverter

Externally fitted to a transceiver to enable both transmission and reception on a band other than what it normally covers. An h.f. transceiver, for example, may be able to operate on the 144MHz band, (2 metres), when tuned to the 28MHz band, (10 metres).

Converters

Externally fitted to the aerial terminals of a receiver to provide reception of a band that the receiver does not cover. For example a converter may be used to receive 144MHz, (2-metres), giving an output on say 14MHz to enable tuning on an h.f. receiver.

Repeaters

A transmitter, fed by a receiver, re-transmits a received signal but on a different frequency. Repeaters are often situated on a high hill and used mainly on v.h.f. (2-meters), and u.h.f. (70cms). They extend the range of communication from what would otherwise normally be not too much more than 'line-of-sight'.

Assignment 17.

1. The a.g.c. voltage in a receiver -

   A. Decreases the audio output as the received signal strength increases.
   B. Increases the receiver gain as the received signal strength increases.
   C. Decreases the receiver gain as the received signal strength increases.
   D. Is independent of the received signal strength.

2. A direct conversion receiver -

   A. Has no local oscillator.
   B. Has no mixer.
   C. Is not a practical receiver for frequencies above about 2 MHz.
   D. Has the frequency of the local oscillator set to the same carrier frequency as the incoming signal.

3. A product detector is a circuit that -

   A. Is a sensitive indicator of spurious emissions.
   B. Produces an indication of lock in a synthesised oscillator.
   C. Is a good frequency multiplier.
   D. Has audio output by mixing 2 higher frequency signals.

4. The frequency of the local oscillator in a receiver tuned to a station on 3500 kHz is 4000 kHz. Which of the following frequencies (in kilohertz) would appear at the output of the receiver's mixer before any tuned circuits are connected?

   A. 500.
   B. 500, 3500, 4000 and 7500.
   C. 3500 and 4000.
   D. 3500, 4000 and 7500.

5. The signal path through a single conversion superheterodyne SSB receiver is -

   A. RF amplifier, mixer, IF amplifier, product detector, audio amplifier.
   B. IF amplifier, mixer, RF amplifier, product detector, audio amplifier.
   C. RF amplifier, local oscillator, mixer, IF amplifier, BFO, audio amplifier.
   D. Mixer, RF amplifier, IF amplifier, product detector, AGC amplifier, audio amplifier.

6. To take full advantage of improvements made to a receiver's selectivity it may be necessary to -

   A. Increase its audio bandwidth.
   B. Reduce its audio output power.
   C. Reduce oscillator frequency drift.
   D. Reduce its input signal dynamic range.

7. The sensitivity of an FM receiver can be expressed in terms of the aerial signal to produce a defined magnitude of -

   A. De-emphasis.
   B. Deviation.
   C. Quieting.
   D. AGC.

8. In certain receivers the strongest signal received will be the only signal intelligibly demodulated even if it is only 2 or 3 times stronger than the other station on the same frequency. This applies -

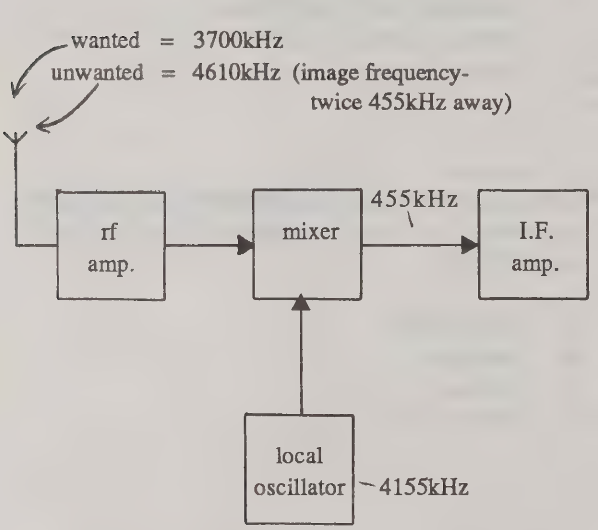
   A. To FM and is known as capture effect.
   B. To FM and is known as de-emphasis effect.
   C. To SSB and is known as capture effect.
   D. To SSB and is known as de-emphasis effect.

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Receiver details

Receiver deficiencies

1. Image interference- second channel interference, a problem with the single conversion superhet. An unwanted signal, on a frequency equal to twice the I.F. frequency away from the one to which the receiver is tuned, is also received.



The local oscillator is set to 4155kHz to receive the wanted 3700kHz signal. This produces the required 455kHz difference for the I.F. amplifier.

If an unwanted signal transmitting on 4610kHz reached the mixer and mixed with the local oscillator, this would also appear on 455kHz and go into the I.F. amplifier. Both signals will be received.

(Alternatively, one signal can appear twice on the dial. Taking just the 3700kHz signal as an example, it will be heard correctly when the receiver is tuned to 3700kHz but will appear again, twice the I.F. away, when the receiver is tuned to 2790kHz).

To reduce image interference:

i) use a tuneable r.f. amplifier. This will reduce the strength of signals reaching the mixer that are not the same frequency as what the receiver is tuned to.

ii) raise the I.F. frequency, making the image frequency further away, and improving the possibility of r.f. and mixer tuned circuits to eliminate it.

2. Audio image- a problem with the simple direct conversion receiver discussed in the last lesson. Similar to image interference, the receiver responds to signals on both sides of the oscillator, but with the simple direct conversion receiver, equally, because the image is extremely close due to the low 'I.F' of virtually 0Hz. A tuneable r.f. amplifier cannot help. A more complex design is required using phasing techniques similar that used in ssb generation.

3. Blocking- a receiver cannot cope with the presence of a strong signal on some other frequency to which it is tuned, and becomes desensitized, reducing the strength of the wanted signal. There is no special relationship between wanted and unwanted signals.

4. Intermodulation- a strong signal overloads the receiver allowing that signal and some other signal to 'mix', producing a new signal inside the receiver that will appear on the 'dial'.

5. Cross modulation- a strong signal overloads the receiver and 'superimposes' itself upon a wanted weaker one.

6. Spurious signals- spuries, birdies, whistles: generated within the receiver and may be caused by harmonics from the receivers internal oscillators.

7. Oscillator noise- reciprocal mixing. If the local oscillator is not pure and has tiny noise sidebands either side of its frequency, a strong r.f. signal adjacent to the wanted frequency could mix with these sidebands, and produce an output at the I.F. frequency.

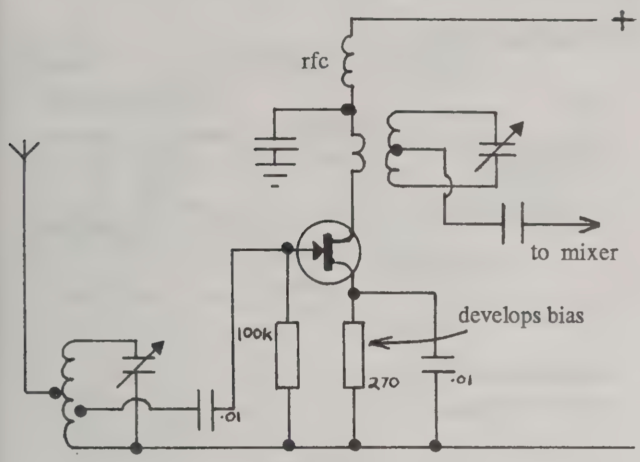
R.F. amplifiers

i) reduce image interference with their tuned circuits,

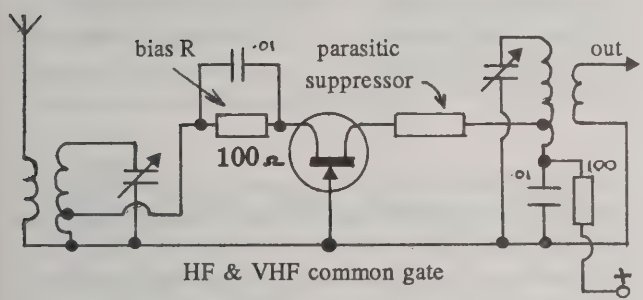
ii) provide amplification ahead of the mixer, (which is inherently noisy), to give good signal-to-noise ratio. This stage will determine the receivers noise factor.

iii) reduce radiation of the local oscillator through the aerial.

RF amplifiers must be low noise, especially at v.h.f. and higher. Here frequencies are quieter than on h.f. where there is often alot of 'atmospheric' noise.



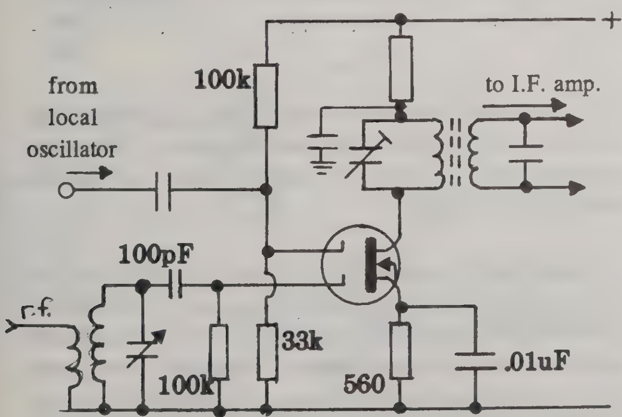
HF common source rf amp.



HF & VHF common gate

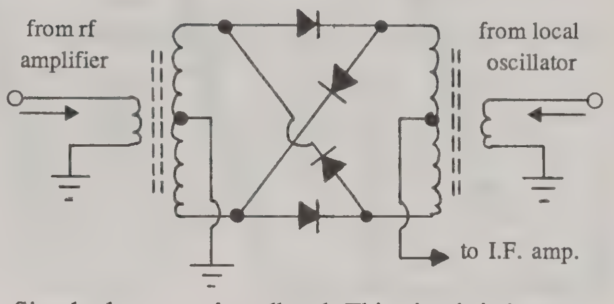
Mixer

A non-linear stage producing sum and difference frequencies, (refer page 15.2). (The original signals can also appear at the output but are not used). A relatively noisy stage. A mixer can determine a receivers dynamic range, and therefore how well it copes, before blocking, intermodulation or cross-modulation occurs.



Has conversion gain. Amplitude of oscillator signal is about ten times that of the r.f. signal.

'Balanced-mixers', (linear, refer page 15.2), are now used in many receivers with advantages.

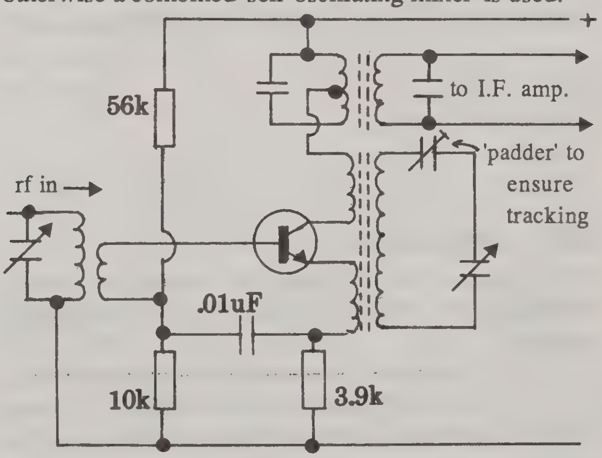


Simple, low cost, broadband. This circuit is known as doubly balanced and provides good 'port-port' isolation, reducing the possibility of local oscillator radiation via the aerial. Hot-carrier, (Schottky, refer page 9.3), diodes may be used to give an excellent dynamic range of over 100db and a low noise figure. A passive circuit, causing a signal loss or 'conversion-loss'.

A mixer stage in conjunction with a local oscillator enables a signal to be changed in frequency, the two making up what is called a frequency 'converter' stage.

Local oscillator

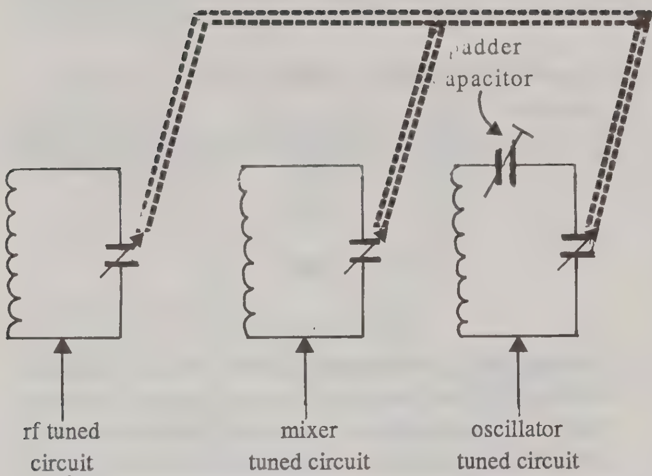
Oscillator frequency stability is important to avoid drift. A separate oscillator is found in good receivers, otherwise a combined 'self-oscillating mixer' is used:



self-oscillating mixer

Tracking- keeping the same frequency difference between rf/mixer tuned circuits and oscillator tuned circuit, when varied simultanously by a 'ganged' capacitor.

To do this, the oscillator has to cover a different tuning range than that of the rf stage or mixer. (The rf stage and mixer tuned circuits are always tuned to the same frequency). Therefore a 'padder' capacitor is used to limit the oscillators range.



Tuning range is say:
3000kHz to 9000kHz = 3 : 1

For 455kHz I.F. the oscillator frequency must always be maintained 455kHz above the signal frequency. Therefore tuning range is:

3455kHz to 9455kHz = 2.7 : 1

This range is smaller, hence the need for a padder capacitor to limit the oscillator's tuning range.

I.F. amplifiers

Provide most of the gain before the detector and usually comprises two or three stages. Its fixed frequency enables:

i) easy design of high gain yet stable stages,

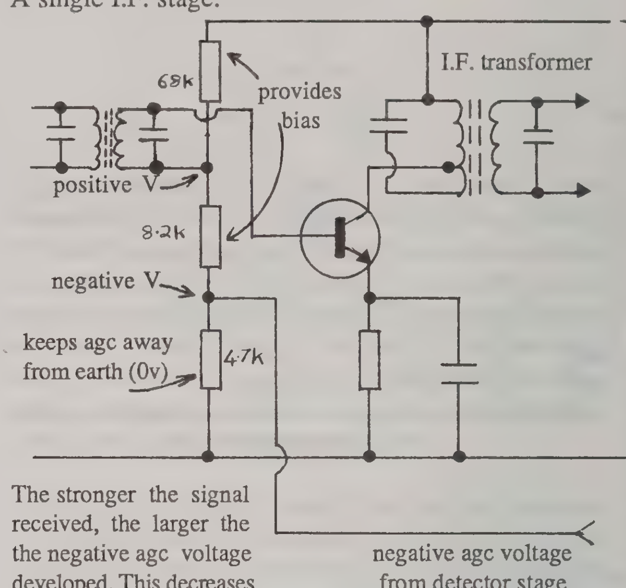
ii) use of high Q tuned circuits (I.F. transformers), and filters to provide the selectivity required to prevent adjacent channel interference.

A low I.F. frequency results in:
1. better selectivity
2. poor image rejection
3. more stability
4. more gain.

A high I.F. frequency gives:
1. worse selectivity
2. easier image rejection
3. prone to instability
4. careful design required to acheive high gain.

The double conversion superhet with its high and low I.F. frequencies obtains the 'best-of-both-worlds' ensuring both good image rejection and good selectivity.

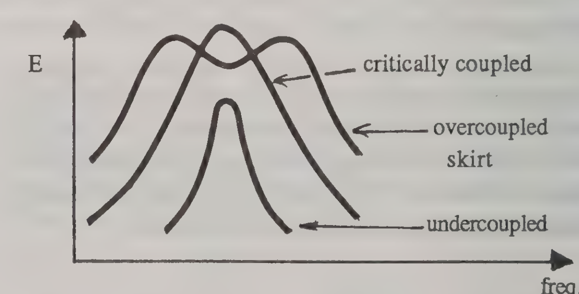
A single I.F. stage:



The stronger the signal received, the larger the the negative agc voltage developed. This decreases the existing positive bias and so reduces the gain of the stage.

I.F. transformers not only couple the signal between stages but, being tuned on both sides, couple only those on and near their resonant frequency. They are 'universally wound', (in a criss-cross manner), to reduce distributed capacitance effects. This will give a high Q. The higher the Q, the better the selectivity.

If the coils are too close, 'critical coupling' is reached, beyond which selectivity decreases.

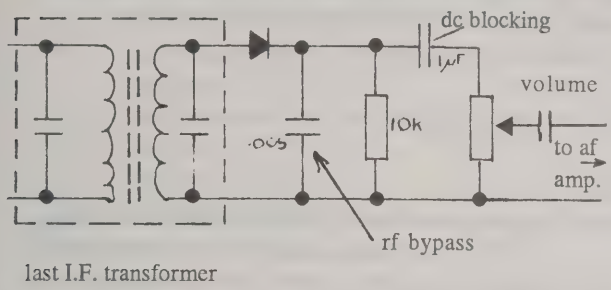


I.F. transformers are usually tuned with a threaded 'slug' core and all aligned to the same frequency. For wider bandwidths, they may be 'stagger-tuned' on slightly differing frequencies.

For improved skirt selectivity, ceramic, mechanical, or crystal filters are used. (Refer page 16.2). The half lattice bandpass crystal filter could be, and for even better skirt selectivity, two of these in 'cascade'. The crystal filter is best placed immediately after the mixer to avoid overdriving the crystals. The filter will introduce some loss though, and will mean that the first I.F. stage will need to have a low noise figure to ensure a good signal-to-noise ratio is maintained.

Envelope detector

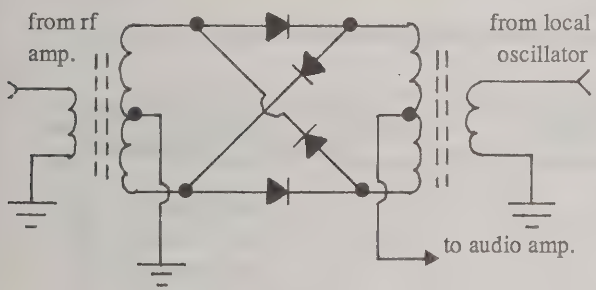
For a.m., inefficient at very low signal levels where it can distort or even lose the intelligibility of a signal.



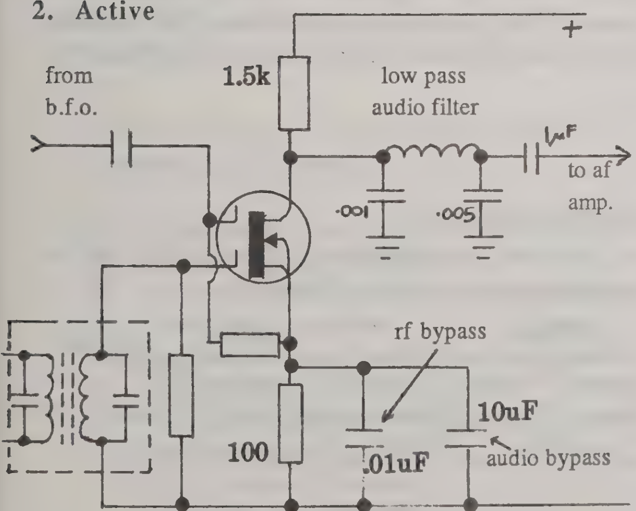
Product detector

For c.w., ssb. Synchronous detection, a 'linear' mixer with an output at an audio frequency. Used in the direct conversion receiver and in conjunction with a b.f.o. in some superhets. Preserves S/N ratio.

1. Passive



2. Active

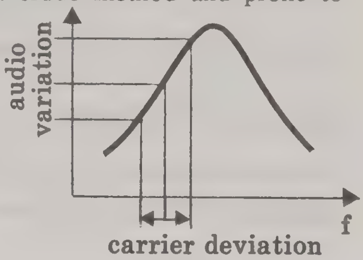


The square-law relationship of FETS makes them ideal as mixers and product detectors by operating on a curved portion of their response characteristic where the drain current is proportional to $Egate^2$

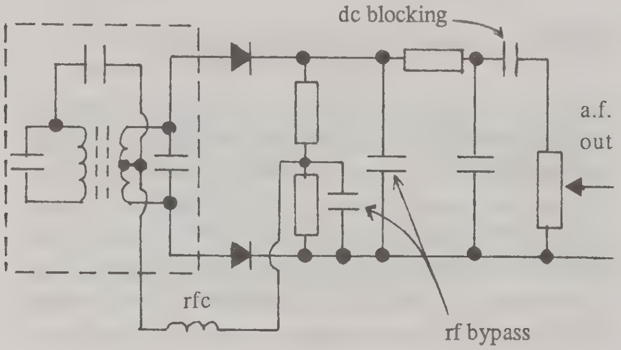
F.M. detectors

Convert frequency changes into amplitude variations.

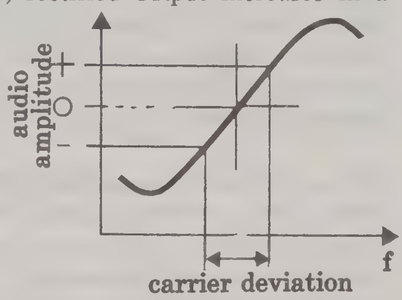
1. Slope detection- a crude method and prone to distortion. A normal a.m. envelope detector is used but the f.m. signal is tuned into the side of the receivers passband curve.



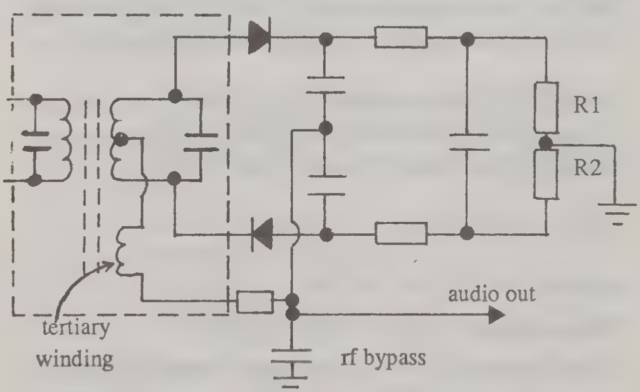
2. Discriminator- Foster-Seeley discriminator



Characteristic curve shows when f.m. signal swings high in frequency, rectified output increases in a positive direction, (and in a negative direction when signal swings low in frequency). The discriminator must have a limiter stage preceding it.



3. Ratio detector

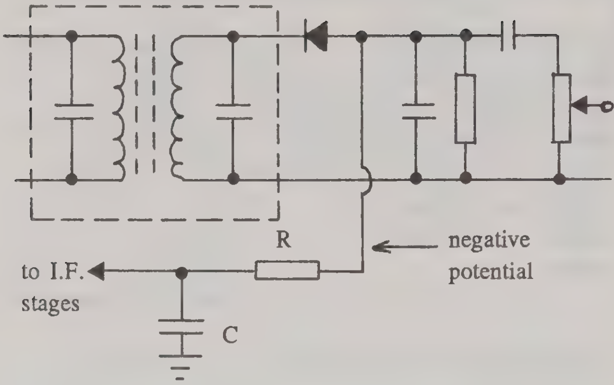


The audio output is determined by the ratio of d.c. voltage developed by the rectified signal across R1 and R2, and is taken from the 'tertiary' winding of the transformer.

Because this detector only responds to ratios, and not signal strength variations, it does not need a limiter stage. The sensitivity of the ratio detector is one half that of the discriminator.

A.G.C.

Automatic gain control.



a.m. diode detector with 'simple' a.g.c.

The a.g.c. voltage depends upon r.f. signal strength and is applied to each I.F. stage, and often to the r.f. stage. It alters the bias of a stage, and so changes its gain. The stronger the signal, the larger the voltage rectified by the diode, the larger the negative a.g.c. voltage produced. This lowers the transistors normal positive bias in each stage a little, (NPN transistors), and reduces their gain. A CR time constant smooths out the effects.

Simple agc is unsatisfactory for c.w. and ssb because the b.f.o. signal would look like a strong r.f. signal and therefore reduce the gain of the receiver. Alternatively the a.g.c. voltage can be derived before the b.f.o. injection point, at the final I.F. stage for example, and fed into a separate special a.g.c. amplifier and diode.

For c.w. and ssb reception a fast 'rise' or 'attack' time of 10msec, and a slow 'hang', 'decay', or 'release' time of 0.5sec. is preferred. The fast rise time ensures immediate action to avoid overloading of the receiver. The slow hang time keeps the gain down a while until the next morse character or word is received. Otherwise, the receiver gain would rise up and down quickly, producing an unpleasant sounding 'pumping' of background noise.

To ensure the best possible signal-to-noise ratio, the application of a.g.c. to the r.f. stage may be delayed until the signal goes above a certain level. (Delayed a.g.c.).

Receiver r.f. controls

When the presence of a strong signal causes overloading such as cross-modulation, switch in the **r.f. attenuator**. The **r.f. gain** may be used if the receiver does not have one. Otherwise set the r.f. gain at maximum for a.m., but with c.w./ssb: in older receivers, (which may not have 'fast rise/slow hang' type of a.g.c.), turn off a.g.c., back off r.f. gain on stronger signals to provide correct 'b.f.o. injection/signal' ratio.

In modern receivers often the r.f. gain adjusts the a.g.c. voltage, and is normally left at maximum. The r.f. gain may be backed off to give more pleasant listening conditions with ssb. It will overide the normal a.g.c. action, and keep the receiver gain down, (including the background atmospheric noise), during the longer pauses in transmission.

B.F.O.

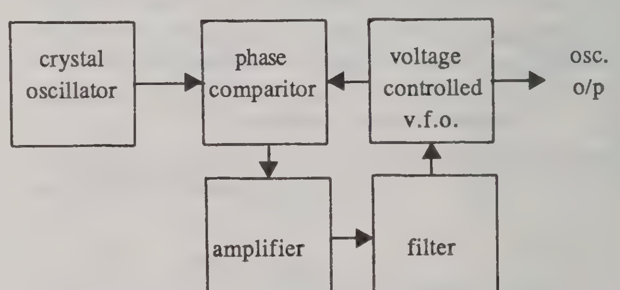
Beat frequency oscillator, carrier insertion oscillator:

Older receivers use an LC oscillator with a 'pitch' control on the front panel. This varies the b.f.o. frequency plus or minus 5kHz from the centre of the I.F. frequency. Difficult to ensure proper setting.

Modern receivers use a crystal controlled oscillator that is easier to use and has good frequency stability. There is no pitch control but a 'mode' switch selects between three crystals, allowing three slightly different b.f.o. frequencies. This enables c.w., usb, or lsb reception with the reinserted 'carrier' (b.f.o. signal) falling on the correct side for the particular sideband.

PLL

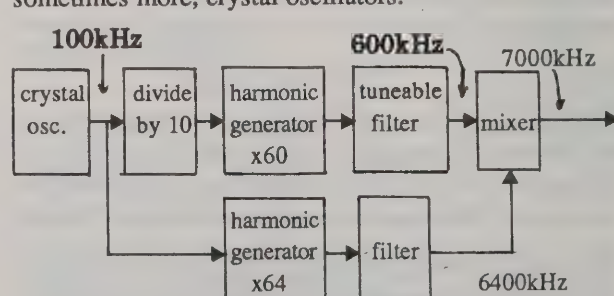
Phase-locked loop, provides stability for v.f.o's.



If the v.f.o. drifts in frequency the phase comparitor will detect this and generate an error voltage. This is applied to the voltage controlled v.f.o., correcting its frequency.

Synthesizer

A range of frequencies are derived from one, or sometimes more, crystal oscillators.



The multiplication factors may be switched to some other figure to produce a different output frequency.

Assignment 18.

1. The frequency separation between a station and its received image in a superheterodyne receiver is -

   A. The frequency of the station plus the IF frequency.
   B. The frequency of the station minus the IF frequency.
   C. The IF frequency.
   D. Twice the IF frequency.

2. The transfer of intelligence from a strong unwanted signal to a wanted weak one is termed-

   A. Cross-modulation.
   B. Blocking.
   C. Third order intercept.
   D. Intermodulation.

3. Which of the following stages have the most effect on a receiver's noise figure?

   A. RF amplifier.
   B. Mixer.
   C. IF amplifier.
   D. AF amplifier.

4. The main purpose of the RF gain control on a communications receiver is -

   A. To reduce the front end gain of the receiver to prevent first mixer blocking.
   B. To augment the range of the audio gain control at low volume.
   C. To optimise the receiver for the desired mode of reception.
   D. To enable the receiver to respond to higher frequencies than would normally be possible.

5. In the context of receivers the term oscillator tracking means -

   A. Keeping the feedback sufficient for oscillation over the band.
   B. Having a reasonably linear display of input frequency.
   C. Keeping the oscillator frequency drift constant over the band.
   D. Keeping the difference between the oscillator and signal frequencies constant over the band.

6. Decreasing the coupling between 2 critically coupled parallel tuned circuits -

   A. Decreases the bandwidth of the arrangement.
   B. Has no effect on the selectivity of the arrangement.
   C. Decreases the selectivity of the arrangement.
   D. Increases the voltage induced into the secondary tuned circuit.

7. Which of the following would be used in an FM telephony receiver?

   A. Product detector.
   B. Beat frequency oscillator.
   C. Envelope detector.
   D. Ratio detector.

8. The difference between a "simple" and a "delayed" AGC system is that -

   A. "Simple" systems can be overloaded by the BFO but "delayed" systems are not.
   B. "Delayed" systems have a much longer "hang" time.
   C. "Simple" systems do not follow signal level variations very rapidly.
   D. "Delayed" systems will not act until a certain signal level is reached.

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Discussion

Its time to ease up on the pressure a little, reflect on the course, have a look at the projects we have built, and compare 'notes'. First, a few words on capacitor useage.

Capacitor usage

In Lesson 5 capacitors were introduced, but their use in various types of circuits could not be dealt with. Different types of capacitors are better suited to some frequencies and tasks than others are. Because of their physical construction, some capacitors start to exhibit 'self-inductance' at higher frequencies and will be less efficient. Generally, capacitors are used as follows:

Polyester- audio amplifiers: coupling
Electrolytic- audio: decoupling, coupling.
power supplies: reservoir.
Tantalum- audio: decoupling, coupling.
Disc Ceramic- r.f. amplifiers: decoupling, coupling.
Feedthrough- r.f. (v.h.f., u.h.f.), decoupling.
Polystyrene- r.f. tuned circuits.

Projects

On page 6.3 in Lesson 6 encouragement to do some practical work, such as small kitsets, was given. Each member of the class may show their projects, say how they went about it, and discuss any problems.

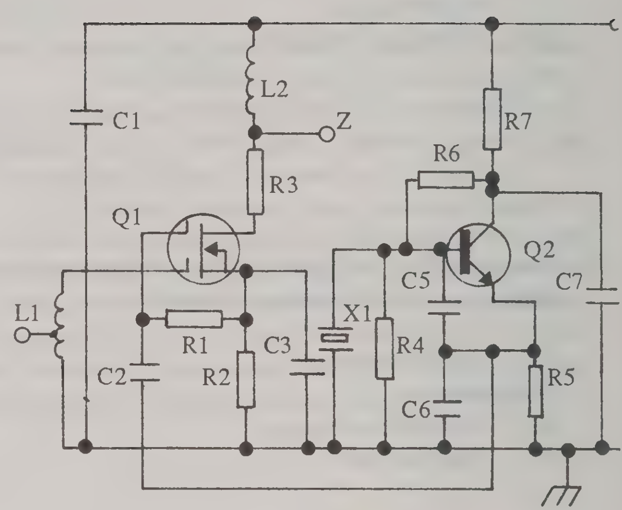
Circuits

In the examination, circuits are quite often shown with a set of questions relating to the purpose of some of its individual components and even the function of a particular stage or circuit. To help identify a stage try to work through these two rules:

(i) Is it a.f. (look for microphones/loud-speakers), or r.f. (tuned circuits/aerials)?

(ii) Is it an amplifier (look for input as well as output), or is it an oscillator (output only/ feedback path/Hartley tapped coil/Colpitts 'tapped- capacitor')?

Here is a typical circuit from a past paper with some questions.



1. What type of devices are these and what are the function of their stages: i) Q1 ii) Q2

2. Where would this circuit be found?

3. What is another name given to the overall circuit?

4. What is the terminal marked "Z" used for?

Some past questions, courtesy NZPO:

5. Resistor R6 -
   A. Is part of the bias network.
   B. Controls the frequency response of the oscillator.
   C. Is included to polarise X1.
   D. Is included to prevent Q2 from oscillating.

6. Capacitor C7 is -
   A. An RF feedback capacitor.
   B. An RF interstage coupling capacitor.
   C. An RF decoupling capacitor.
   D. To tune the oscillator output.

7. Capacitor C2 is -
   A. An RF feedback capacitor.
   B. A DC smoothing capacitor.
   C. An RF interstage coupling capacitor.
   D. An RF decoupling capacitor.

Assignment 19.

1. An advantage of an electrolytic capacitor is :

   A. The large capacitance obtainable for a small physical size.
   B. Low dielectric loss.
   C. That it can bypass both radio and audio frequencies.
   D High dielectric loss.

2. A negative temperature coefficient capacitor is -

   A. Used as a voltage regulator.
   B. One in which the capacitance decreases with an increase in temperature.
   C. One in which the capacitance increases with an increase in temperature.
   D. Used to counter drift in tuned circuits.

3. Ceramic feedthrough capacitors are generally used to -

   A. Reduce mains and rectifier hum in power supplies.
   B. Decouple leads passing through a shield.
   C. Reduce harmonics in a power amplifier output network.
   D. Neutralise amplifiers that have unwanted oscillations.

4. Which of the following devices would be most likely to be used in a modern receiver's RF stage -

   A. Point contact transistor.
   B. Triode-hexode.
   C. Nuvistor.
   D. Field effect transistor.

5. A field effect transistor is suited to frequency conversion applications because -

   A. The high input impedance improves linearity.
   B. Of the basic square law characteristic of the device.
   C. The local oscillator signal does not appear in the output.
   D. The RF signal does not appear in the output.

6. In a receiver using a crystal filter to determine the overall selectivity, unwanted signals are best rejected when :

   A. Most of the receiver gain is after the filter.
   B. The receiver gain is evenly distributed before and after the filter.
   C. Most of the receiver gain is before the filter.
   D. A crystal filter is used which is insensitive to the receiver gain distribution.

7. A type of diode useful for mixer or detector circuits well into the microwave region is the -

   A. Hot-carrier diode.
   B. Zener diode.
   C. Alloy-diffused diode.
   D. Light-emitting diode.

8. When comparing germanium diodes with silicon diodes, which of the following is true of germanium diodes?

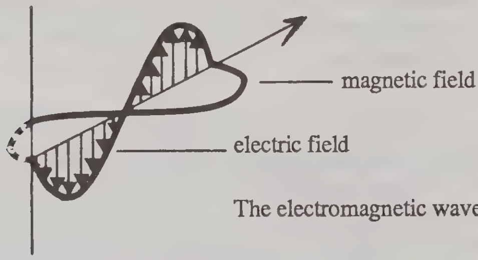
   A. High thermal dissipation; used as power diodes.
   B. Low reverse breakdown voltage rating; used as zener diodes.
   C. Low barrier capacitance; used as a.g.c. devices at VHF.
   D. Low forward voltage drop; often used as detectors.

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Have you sent in your application to sit the exam yet? Don't delay!

Aerials

An aerial, or antenna, is a length of conductor from which energy is radiated from in the form of electromagnetic waves into, or received from, space.



The electromagnetic wave

The electromagnetic wave is comprised of an electric field and a magnetic field at right angles to one another.

Transmission lines

Carry power from transmitter to aerial, or signal from aerial to receiver, with a minimum of loss.

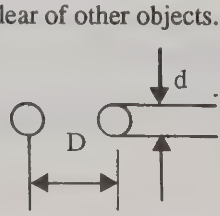
Characteristic impedance, (Zo)- a value of a particular transmission line and is given in ohms (Ω). It is equal to the ratio of applied voltage to the resultant current in an <u>infinitely</u> long line, irrespective of what is terminated at its end.

$$Zo = \frac{E \text{ applied}}{I \text{ flowing}} \quad \text{(in an infinite line)}$$

This value is determined by the physical dimensional ratios of cross-section of line and <u>not</u> by its overall size.

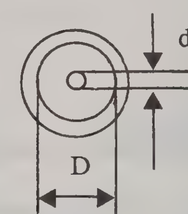
$$Zo \quad \text{is proportional to} \quad \frac{D}{d}$$

a) Parallel wires: twin line, balanced with respect to earth, must be kept clear of other objects.



Typically 300Ω to 600Ω.

b) Concentric lines: coaxial, unbalanced because one side is earthed, can be run alongside other objects, more lossy than parallel wires. Zo typically 50 - 75Ω.



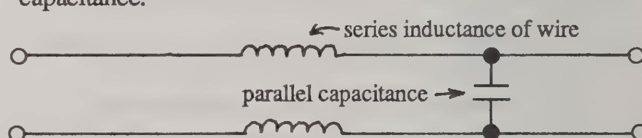
Characteristic Impedance may also be expressed:

i) Zo = input Z of <u>infinite</u> line

ii) $Zo = \frac{E \text{ of travelling wave on line}}{I \text{ of travelling wave on line}}$

for a <u>finite</u> line, (terminated with resistance equal to Zo)

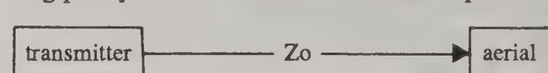
iii) any transmission line will have inductance and capacitance:



$$\text{therefore } Zo = \sqrt{\frac{L \text{ per unit length of line}}{C \text{ per unit length of line}}}$$

Characteristic impedance is not something that can be measured with an ohm-meter. Nor will a perfect line consume any power, but rather, deliver it to the aerial.

To ensure maximum transfer of power to the aerial, the transmitter's output impedance, line's characteristic impedance, and the aerial's impedance must all 'match', (equal each other in value), and the aerials impedance being purely resistive with no reactive components.



$$Z_{tx} = Zo = Z_{aerial} \text{ (resistive)}$$

The line may be any length and under these matched conditions is said to be 'flat' or 'untuned'.

Velocity factor- the amount by which the speed of the wave travelling in a transmission line is slowed down compared to that of free space.

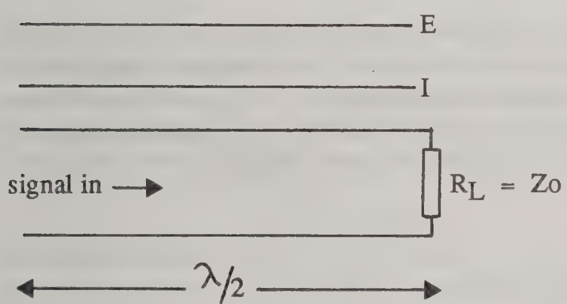
Typical figures:	twin line	= 0.82
	coax cable	= 0.66

Standing waves- distribution along a transmission line of maximum (antinode) and minimum (node) values of voltage and current which are set up if the line is not terminated with a 'resistive' aerial and/or one that is not the same value as the lines characteristic impedance.

The line is 'not-matched', and not all the power is dissipated in the aerial or load, but some is reflected back down the line. The reflected wave 'meets' the forward wave, combines with it, setting up the nodes and antinodes called standing waves.

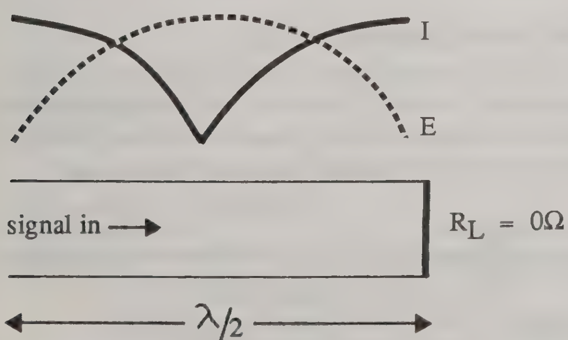
Three examples of different terminations on a line having a length equal to one half of a wavelength for the particular signal being fed in-

i) The load is resistive and equals Zo:



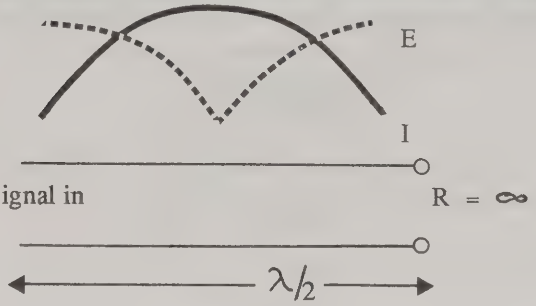
No standing waves, all forward power is dissipated in the load.

ii) The end of the line is 'short-circuit':



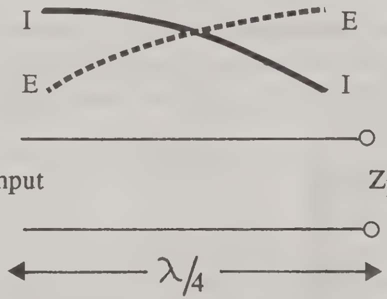
Standing waves of voltage and current are set up. At termination end: maximum current, minimum voltage.

iii) The end of the line is 'open-circuit'-



Standing waves of voltage and current are again set up. At termination: minimum current, maximum voltage.

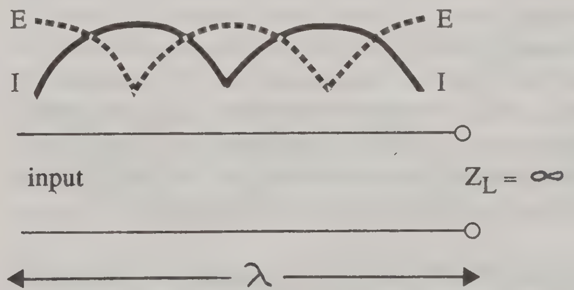
In a standing wave, the conditions of voltage, current, and therefore impedance, are completely opposite every quarter wavelength along the line:



At load: $\frac{\text{max E}}{\text{min I}} = \text{max Z}$

At input: $\frac{\text{min E}}{\text{max I}} = \text{min Z}$

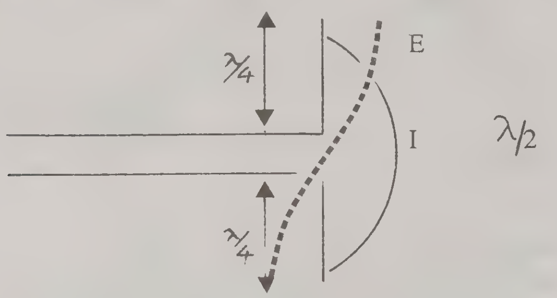
Conditions repeat themselves every half wavelength along the line:



At load: $\frac{\text{max E}}{\text{min I}} = \text{max Z}$

At input: $\frac{\text{max E}}{\text{min I}} = \text{max Z}$

Aerial derivation- imagine a transmission line is opened out a quarter of a wavelength from its end.



The impedance at the bend will be low. If this matched the line's characteristic impedance, there would be no standing waves on the transmission line.

Standing waves will appear on the opened up portion and radiate an electromagnetic wave. This portion is called a 'radiator' or aerial. (This aerial being a half-wavelength long is called a half-wave dipole).

Note- if an unbalanced line was connected to this balanced aerial, r.f. currents would flow on the outer braid of the cable, causing radiation from the cable.

Standing wave ratio, (S.W.R.)- the ratio of maximum and minimum values of the standing wave along the line. Either voltage (E), or current (I), values can be used.

$$SWR = \frac{E\,max}{E\ min} \quad \text{or} \quad \frac{I\ max}{I\ min}$$

For purely resistive load:

$$SWR = \frac{R\ load}{Zo} \quad \text{or} \quad \frac{Zo}{R\ load}$$

The ideal s.w.r. ratio is generally accepted to be 1:1 where no standing waves are present. However, although a low s.w.r. does make life easier, it does not necessarily mean the aerial is a good one, or that it is working efficiently. It may be suffering from resistance losses such as from poor connections, a poor earthing system, or lossy cable. (For example, an s.w.r. of 1:1 can be obtained by terminating the line with only a resistor- but it won't radiate a signal very far)!

On the other hand, a high s.w.r. may not mean that very much power is ultimately lost. If a line had no losses, all the power that was reflected would end up back at the transmitter end. Now, as long as the transmitter was correctly tuned and coupled to the line, all of this reflected power would be re-reflected and travel forward again towards the aerial. As before, some will be absorbed by the aerial and the same proportion reflected back again. This process will repeat itself over and over until all the power is ultimately absorbed by the aerial.

Problems arise from a high s.w.r. only if:

i) the cable is lossy at the frequency being used. All lines have some loss that will attenuate a signal, and these losses increase with higher frequencies. A high s.w.r. on a lossy line, (more likely at v.h.f. and u.h.f.), can cause significant power loss to a signal that has travelled back and forth alot, suffering attenuation each time it does so.

ii) the transmitter is not correctly coupled to the line or tuned properly. The transmitter 'sees' the impedance of E divide by I created by the standing wave. This impedance must be within the range of values the transmitter is designed to load into. Otherwise, the final p.a. stage will be less efficient, causing an increase in collector dissipation, and may overheat and even destroy the transistor.

Modern transmitters are designed for a nominal load impedance of 50 ohms and a maximum s.w.r. of 2:1. If these requirements are not met, operation can be still possible though. A suitable matching network or "aerial tuning unit" can be inserted between the transmitter output and the line to give correct coupling. The subsequent s.w.r. on the line will not affect the transmitter.

Smith Chart- a special circular graph using curved, rather than rectangular, coordinate lines, and is used to determine parameters such as impedances, voltages, currents, and s.w.r. This avoids the complex mathematical calculations that would otherwise need to be made.

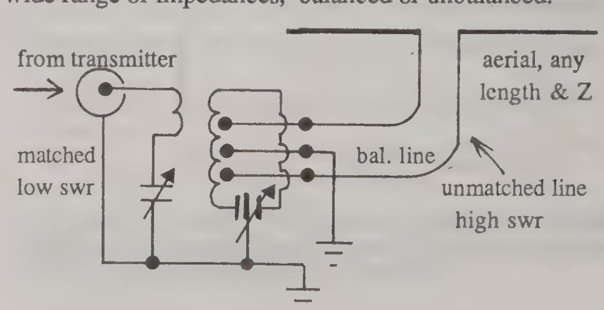
Power limit- that amount of r.f. power the line can carry before either:

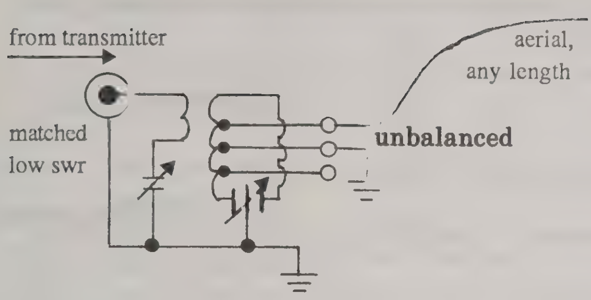
i) the conductors overheat and deform or damage the insulation, or

ii) voltage breakdown occurs between conductors, being more likely with high s.w.r.

Matching methods

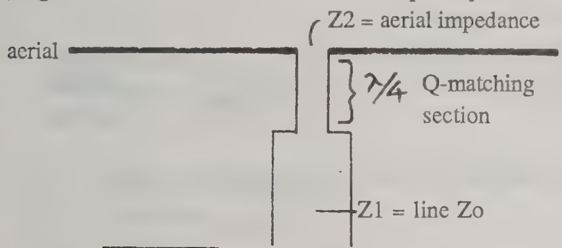
1. Aerial tuning unit (a.t.u.)- aerial coupler, transmatch. A special circuit of coils and capacitors to enable a transmitter to be matched to lines having a wide range of impedances, balanced or unbalanced.





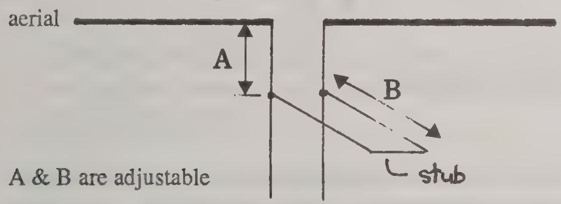
2. Line transformers- a 'tuned-line', to match transmission line to aerial. A set length for the frequency of operation. Uses the principle of a line with standing waves having different impedances at each end.

a) Quarter-wave section- fixed frequency.



$Z_m = \sqrt{Z1 \times Z2}$ where Zm = impedance of Q-matching section

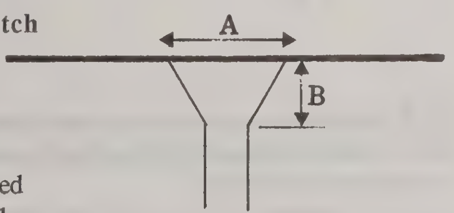
b) Stub-matching-



A & B are adjustable

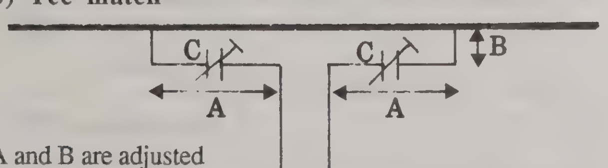
3. Tapped aerial matching- the impedance at the centre of a half-wave aerial is low, but rises either side. A match can be obtained by tapping the transmission line along a bit from the centre of the aerial.

a) Delta match



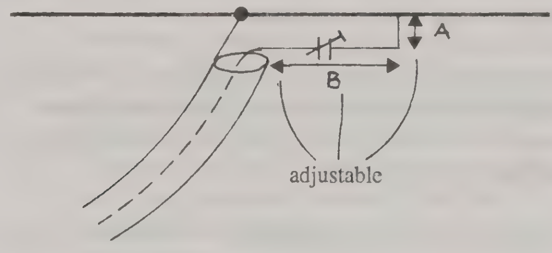
A and B adjusted
for swr of 1 : 1

b) Tee match



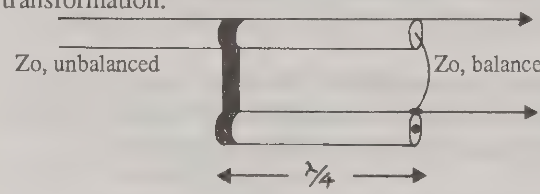
A and B are adjusted
for the correct match.
C tunes out the inductance caused by the coupling arms.

c) Gamma match- for use with unbalance coaxial lines.

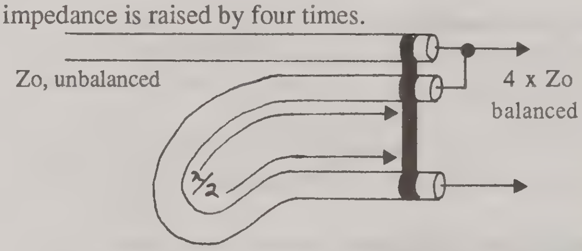


4. Balun- **Bal**anced to **un**balanced, or vice-versa.

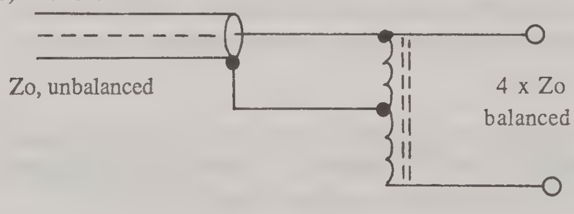
a) Coaxial λ/4 balun- Pawsey stub, no impedance transformation.



b) Coaxial λ/2 balun- the characteristic impedance is raised by four times.



c) Toroid balun- broadband



Properties of aerials

Polarization- the position of the aerials radiating wire or element with respect to earth and corresponds to the electric component of the electromagnetic wave.

Radiation Resistance- a fictitious resistance that accounts for the power radiated by the aerial.

$$\text{Radiation Resistance} = \frac{\text{P radiated}}{\text{I aerial}^2} \qquad (P = I^2 R).$$

Gain- the increase in power in a given aerial's direction of maximum radiation, compared with a single 'half-wave dipole' aerial fed with the same power.

Front-to-back ratio- for aerials that have gain, the ratio in db of power radiated in the favoured direction to the power radiated in the other.

Bandwidth- the range of frequencies over which the aerial can be used to obtain good performance. The lower the operating frequency of a given aerial, the narrower the bandwidth.

Height- as high as possible, (10 metres a popular compromise for horizontal aerials). Should be above immediate obstacles. At v.h.f. a greater than 6db gain is often obtained every time height is doubled.

Earth- any connection that forms part of the aerial system should be taken to a separate copper stake, over a metre long, and not to the mains earth connection.

Length- expressed in terms of wavelength for frequency used but in practice is about 5% less than that for 'free-space', due to 'end-effect' capacitance.

half wave in free space: $\dfrac{150}{F\ (MHz)}$ metres

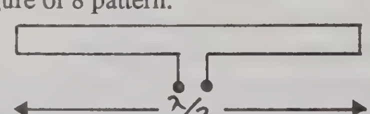
half wave aerial length: $\dfrac{142}{F\ (MHz)}$ metres

Aerial types

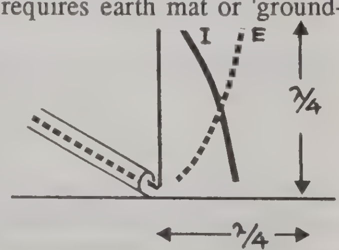
1. Simple wire aerials- random length, centre or end fed. May need to be fed via a.t.u. if the transmitter is not able to provide the correct coupling, (page 20.3).

2. Half-wave dipole- hertz aerial, 73Ω, balanced, radiates figure of 8 pattern, horizontal or vertical, (page 20.3). Very popular and easy to match.

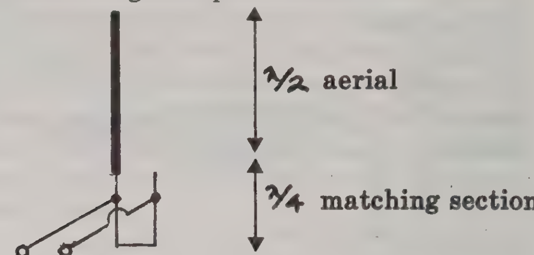
3. Folded Dipole- 300Ω, balanced, horizontal or vertical, figure of 8 pattern.



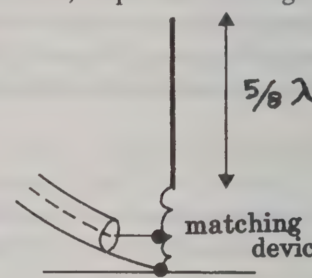
4. Quarter Wave- Marconi, vertical, whip, ground plane, approx 40Ω, unbalanced, can be used directly with 50Ω coax cable, requires earth mat or 'ground-plane' of 'radials', omni-directional, low angle radiation giving strong 'ground-wave'. Gain = -1.2db. If height is less than λ/4, a baseloading coil is added in series.



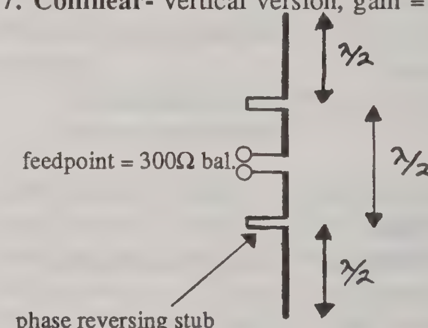
5. J-antenna- no ground plane needed. Gain = 0db.



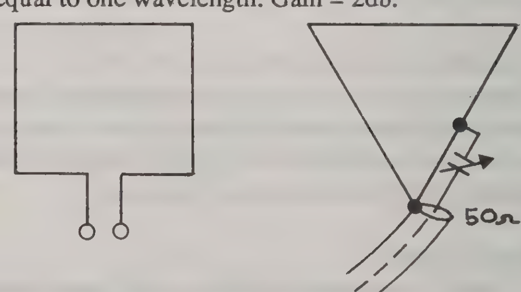
6. Five-eighths- vertical, requires matching device to transmission line, omni - directional. Gain = 1.8db, (3db over quarter-wave whip), because of even lower angle of radiation, radials only λ/4 long.



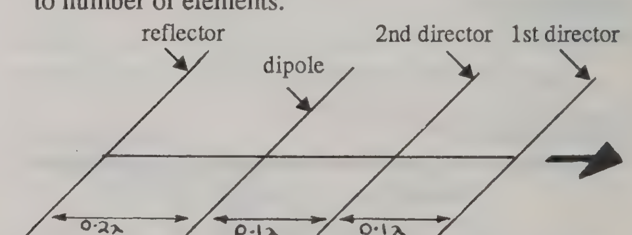
7. Collinear- vertical version, gain = 4db:



8. Cubical quad and delta loops- overall length is equal to one wavelength. Gain = 2db.



9. Yagi- beam, parasitic array, horizontal or vertical, gain in one direction (uni-directional), and proportional to number of elements.



gain approx. = 8db

Reflector is approximately 5% longer than dipole while the directors are approximately 5% shorter than dipole.

Assignment 20.

1. Which of the following applies to a transmission line of infinite length?

   A. The input impedance is half the characteristic impedance.
   B. The ratio of voltage to current is constant over the entire line.
   C. The voltage and current are out of phase at any point on the line.
   D. The input impedance is twice the characteristic impedance.

2. An electrical quarter wavelength of transmission line is short-circuited at its far end. The impedance at the input will appear to be :

   A. A high resistance.
   B. Capacitive.
   C. Inductive.
   D. A low resistance.

3. The principal difficulty in operating a transmitter into a load through an untuned transmission line with a high SWR is -

   A. That the line will radiate.
   B. That the efficiency of the RF power amplifier is reduced.
   C. That most of the RF energy reaching the antenna is radiated as heat.
   D. That most of the RF energy reaching the antenna is radiated as harmonics.

4. The main purpose of an antenna tuning unit (ATU) for amateur transmission is -

   A. To reduce spurious emissions from the transmitter.
   B. To increase the loading on the transmitter.
   C. To decrease the loading on the transmitter.
   D. To provide the required impedance transformation.

5. A radio wave is said to be vertically polarised when-

   A. Its electric component is perpendicular to the earth's surface.
   B. Its magnetic component is perpendicular to the earth's surface.
   C. Its electric and its magnetic components are both perpendicular to the earth's surface.
   D. The direction of propagation is vertical to the earth's surface.

6. A "J" antenna is a useful vertically polarised VHF antenna. The basic radiating arrangement is -

   A. An end fed fullwave antenna.
   B. An end fed quarterwave antenna.
   C. A centre fed halfwave antenna.
   D. An end fed halfwave antenna.

7. When compared with a quarter wavelength vertical antenna a five-eighth wavelength vertical antenna-

   A. Has a high angle of radiation.
   B. Should be fed at the base with 50 ohm coaxial cable.
   C. Requires a matching device if fed at the base with 50 ohm coaxial cable.
   D. Has less gain.

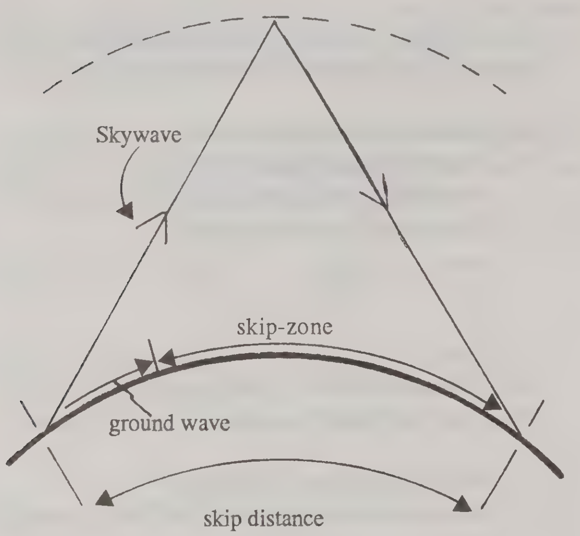
8. The gain of a VHF yagi antenna is mainly dependent upon -

   A. The number of director elements used.
   B. The conductivity of the metal used for the elements.
   C. The diameter of the driven element.
   D. The use of a folded dipole as the driven element.

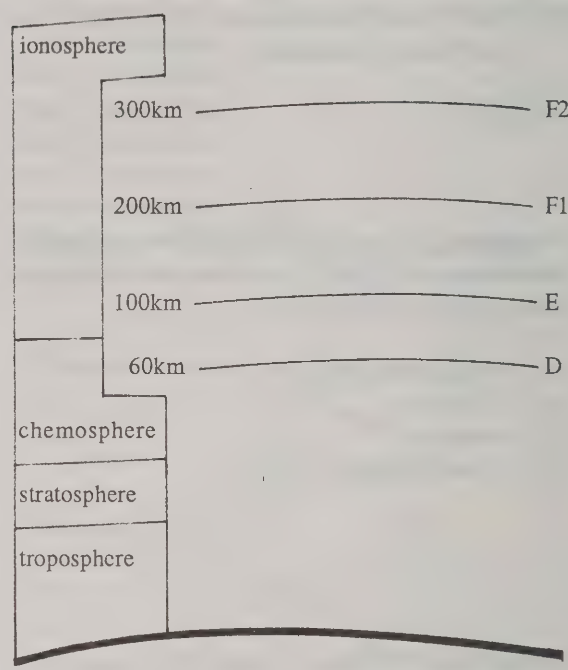
All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Propagation

Radio waves travel through the earth's atmosphere at the speed of light, (300,000,000 metres per second).



The atmosphere-



Ground wave propagation

Follows the earths surface but suffers attenuation as frequency increases by losing energy to the ground. This is especially evident above 2MHz.

Ionospheric propagation

By 'sky-wave', responsible for long distance communication for a range of frequencies 500kHz to 30MHz, (and sometimes higher).

Ultraviolet radiation from the sun produces layers of ionised gas in the atmosphere. (An ion can be created when an atom loses some electrons). The free electrons that now exist will reradiate ('reflect') the signal, or just dissipate ('absorb') it, depending upon the degree of ionization, and the frequency involved.

Sunspot cycle- the number of 'sunspots' on the suns surface varies, but rises to a maximum about every 11 years, the next maximum being expected around 1991. The sunspot 'count' determines the degree of ionization in the atmosphere.

F layers- appleton layer, during the day usually 'reflects' waves about 5MHz to 30MHz although up to 60MHz during a sunspot maximum. At night ionization decreases, and the F1 and F2 layers merge together at 250km, reflecting lower frequencies.

E layer- Kennelly-Heaviside layer, its intensity follows sunlight, during the day reflects 5MHz to 10MHz but at night this layer is porous and weak reflecting only 500kHz to 2MHz.

D layer- during the day dissipates ('absorbs') waves of 500kHz to 5MHz allowing no sky-wave propagation, but disappears at night allowing reflection by the E and F layers.

Multi-hop transmission- the skywave on its return is reflected from the ground and returned to the ionosphere enabling world-wide distances to be covered.

Sporadic E skip- clouds of very intense ionization within the E layer can reflect v.h.f. signals up to 80MHz, with skip distances anywhere from 900km to about 2000km for a 'single-hop'. Occurs mostly during mid-summer and sometimes in mid-winter.

Virtual height- group height, equivalent height. A figure given to the height of an ionospheric layer for practical purposes, even though each layer is of some considerable depth. It is determined by sending pulses up vertically from the earth and measuring the time it takes for their return.

Maximum usable frequency (m.u.f.)- the highest frequency which will be reflected from the ionosphere for any particular path. The m.u.f. depends upon the time of day, season of the year, latitude, and, the period the sunspot cycle is in.

Optimum working frequency (OWF)- the highest frequency that will be useable for 90% of the time and is about 15% lower than the predicted m.u.f. for a given path. This gives a 'reliability' margin to allow for the m.u.f. dropping momentarily on that path.

Critical frequency- the highest frequency which will be reflected from the ionosphere when transmitted vertically from the earth.

Absorbtion limiting frequency (ALF)- 'lowest usable high frequency', the lowest frequency which will be reflected by the ionosphere for any particular path.

Tropospheric propagation

Ducting, at v.h.f. and u.h.f. radio waves can be refracted due to changes in the earth's atmosphere. This is normally due to changes in temperature and humidity and occurs during anti-cyclonic weather conditions in early morning and just around sunset. Distances up to 4000km are possible.

Band characteristics

160m (1.8 to 1.95MHz)- day: 200km.
night: several thousand km.

80m (3.5 to 3.9)- day: 150km.
night: reliable coverage up to 2500km.

40m (7.0 to 7.3)- day: quiet, 2500km,
night: noisy but can be world-wide.

30m (10.1 to 10.15)- c.w., can be world-wide.

20m (14.0 to 14.35)- very popular and at times crowded. Worldwide coverage day and night.

17m (18.068 to 18.168)- worldwide during the day throughout the sunspot cycle.

15m (21.0 to 21.45)- very changeable, worldwide, especially during the day except during sunspot minimum years.

12m (24.89 to 24.99)- recent allocation in NZ.

10m (28.0 to 29.7)- excellent worldwide coverage during sunspot maximum years.After darkness the band usually fades right out.

6m (50.0 to 50.15, 51.0 to 53.0)- excellent local signals. Up to 15,000km with sporadic E and tropospheric propagation. Operation in this band may cause television interference.

2m (144.0 to 148.0)- very popular band. Local and semi-local signals up to about 150km and up to 3000km with tropospheric openings..

70cm (430.0 to 449.75)- Mainly local contacts although further with tropospheric openings.

Fading

1. Interference fading- where two or more waves from the same transmitter arrive at the receiver over different and changing paths. Each path is varying in length, and the signals arrive with varying phase with respect to each another.

2. Polarization fading- a continuous change in the polarization of the wave reflected from the ionosphere.

3. Absorption fading- a long period variation in the degree of absorption as the wave passes through the ionosphere or troposphere.

4. Skip fading- an abrupt drop and sometimes complete loss of signal that can occur if the receiver is operating near the m.u.f. If the usual m.u.f. momentarily falls, the skip distance will be increased, bringing the receiver into the skip zone. The signal now flies overhead.

Interference

Interference to others

Ensure the transmitter has no emissions other than on the frequency intended. Check broadcast radio and television reception in the same home.

Diagonal lines on a television picture, (cross-hatching), may be caused by a beat between a transmitter harmonic and the television picture carrier frequency.

Reduce harmonics & prevent parasitics by-

i) good transmitter design.

ii) preventing stray radiation from transmitter and associated leads- use shielding and filtering.

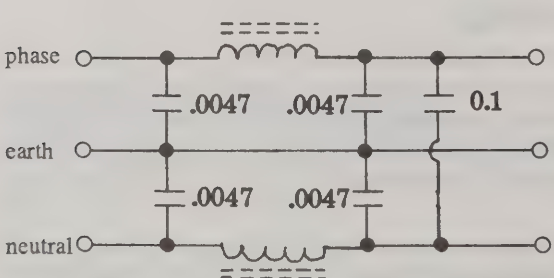
iii) ensuring harmonics are not reaching the aerial- use low pass filter in h.f. transmitter's transmission line at transmitter end.

iv) not 'over-driving' the transmitter but following manufacturer's operating instructions.

If the transmission is 'clean', the equipment suffering interference is likely to be at fault:

Radio deficiencies- cross-modulation, blocking, image. Rectification causing detection in audio stages: fit r.f. bypass capacitors, (0.01µF ceramic).

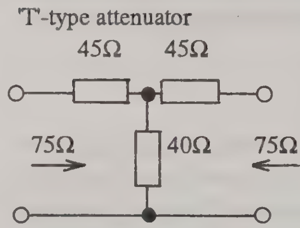
Stereo deficiencies- hi-fi's, rectification in a.f. stages by signal entering via mains, input, or, speaker leads. Fit mains filter, and r.f. bypass capacitors at input and output, (speaker), terminals.

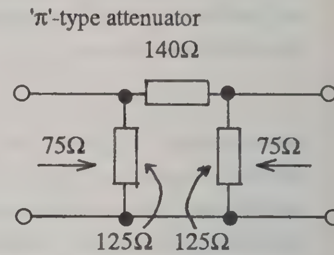


mains filter

Television deficiencies- cross-modulation, blocking- first check television aerial installation. (For example, one lead in twin line ribbon may be broken off at the aerial terminal). Fit filter in tv aerial lead to remove presence of amateur transmission. (High pass filter for h.f. interference).

Sometimes an attenuator instead of a filter may be sufficient to clear cross-modulation without impairing television reception:





Both these circuits will provide 12db attenuation.

Interference to the amateur

Television set line radiation- gurgling buzz ocurring nearly every 16kHz over the band. Also the television set's "PAL switch" will radiate noise. Try television mains and aerial filters, operate only on clear 'spots', or turn television set off!

The real cure is in better design of television sets, and before purchasing a new set, test for this interference in the shop. With one set on at a time, tune across the band with an ordinary transistor radio observing what level of 'hash' is picked up.

Woodpecker- loud sharp clicking noise caused by 'over-the-horizon' radar transmissions. No easy cure.

Ignition- sharp, quick pulse noise caused by cars spark plugs. Most receivers have effective 'noise-blankers'. For mobile operation, fit to car: resistive-core high tension cable and capacitor, (1µF), between ignition coil supply terminal, (marked SW or +), and chassis.

Codes

These save time when conveying information, and also allow international communication with operators who speak little or no English.

The Q-code

The following are from the International Q-code list:

QRG Will you tell me my exact frequency? Your exact frequency is .... kHz

QRH Does my frequency vary? Your frequency varies.

QRI What is the tone of my transmission? The tone of your transmission is .... (T1 - T9)

QRK What is the readibility of my signals? The readability of your signals is .... (R1 - R5).
QRL Are you busy? I am busy. Please do not interfere.
QRM Are you being interfered with? I am being interfered with.
QRN Are you troubled by static? I am troubled by static.
QRO Shall I increase power? Increase power.
QRP Shall I decrease power? Decrease power.
QRQ Shall I send faster? Send faster.
QRS Shall I send more slowly? Send more slowly.
QRT Shall I stop sending? Stop sending.
QRU Have you anything for me? I have nothing for you.
QRV Are you ready? I am ready.
QRW Shall I inform .... that you are calling him on .... kHz? Please inform .... that I am calling on kHz.
QRX When will you call me again? I will call you again at .... hours
QRZ Who is calling me? You are being called by .... (on kHz)
QSA What is the strength of my signals? The strength of your signals is .... (S1 - S9).
QSB Are my signals fading? Your signals are fading.
QSD Is my keying defective? Your keying is defective.
QSL Can you give me acknowledgement of receipt? I give you acknowledgement of receipt.
QSO Can you communicate with .... direct or by relay? I can communicate with .... direct (or by relay through ....).
QSP Will you relay to? I will relay to ....
QSV Shall I send a series of VVVs? Send a series of VVVs.
QSY Shall I change to another frequency? Change to transmission on another frequency (or on .... kHz).
QSZ Shall I send each word more than once? Send each word twice.
QTH What is your location? My location is ....
QTR What is the correct time? The correct time is .... hours.

Amateurs often use the Q-code as nouns rather than the question and answer form. For example:
QRM interference from other stations.
QRN interference from atmospherics or local electrical apparatus.
QRP low power.
QRT close down.
QRX stand by.
QSB fading.
QSL verification card.
QSO radio contact.
QSY change of frequency.
QTH location.

The RST code

For reporting signals. The third number, (tone), is only used for c.w. reports.

Readability
R1 Unreadable.
R2 Barely readable, occasional words distinguishable.
R3 Readable with considerable difficulty.
R4 Readable with practically no difficulty.
R5 Perfectly readable.

Signal strength
S1 Faint, signals barely perceptible.
S2 Very weak signals.
S3 Weak signals.
S4 Fair signals.
S5 Fairly good signals.
S6 Good signals.
S7 Moderately strong signals.
S8 Strong signals.
S9 Extremely strong signals.

Tone
T1 Extremely rough hissing note.
T2 Very rough a.c. note, no trace of musicality.
T3 Rough, low pitched a.c. note, slightly musical.
T4 Rather rough a.c. note, moderately musical.
T5 Musically-modulated note.
T6 Modulated note, slight trace of whistle.
T7 Near d.c. note, smooth ripple.
T8 Good d.c. note, just a trace of ripple.
T9 Purest d.c. note.

If the note appears to be crystal-controlled add X after the appropriate number. Where there is chirp add C, drift add D, clicks add K.

The phonetic alphabet

A	Alfa	**N**	November
B	Bravo	**O**	Oscar
C	Charlie	**P**	Papa
D	Delta	**Q**	Quebec
E	Echo	**R**	Romeo
F	Foxtrot	**S**	Sierra
G	Golf	**T**	Tango
H	Hotel	**U**	Uniform
I	India	**V**	Victor
J	Juliett	**W**	Whiskey
K	Kilo	**X**	X-ray
L	Lima	**Y**	Yankee
M	Mike	**Z**	Zulu

Assignment 21

1. Limited ground wave coverage occurs at HF because of high ground wave -

   A. Refraction.
   B. Attenuation.
   C. Polarization.
   D. Fading.

2. The sunspot number -

   A. Is easiest to measure at night time.
   B. Influences the propagation of radio waves.
   C. Governs the amount of power that can be radiated by an antenna.
   D. Alters the VSWR on a transmission line.

3. The maximum usable frequency for an ionospheric transmission path depends on the -

   A. Polarisation of the transmitted wave.
   B. Bandwidth of the receiver being used.
   C. Transmitter power.
   D. Geographical location of the transmitting and receiving stations.

4. The expression which relates the absorbing ability of the D layer to a particular frequency is -

   A. The MUF.
   B. The ALF.
   C. The FOT.
   D. The OWF.

5. Longer than normal communication paths using the 2 metre amateur band are usually due to -

   A. The D layer of the ionosphere.
   B. Tropospheric ducting.
   C. A reduced sunspot number.
   D. Ground wave propagation.

6. When a spurious signal is generated in the first stage of a television receiver, the resulting interference is known as -

   A. Multipath interference.
   B. Fundamental overload.
   C. Harmonic interference.
   D. Reradiation interference

7. Interference caused by a transmitter to an audio amplifier may be eliminated by :

   A. Placing RF bypass capacitors across the amplifier input terminals.
   B. Changing the transmitter final amplifier to operate in class B.
   C. Operating the transmitter final amplifier in class AB2.
   D. Inserting a low pass filter between the transmitter and its antenna.

8. The most effective way of reducing transmitter r.f. feedback between antenna and microphone would be to :

   A. Insert an audio low pass filter at the input to the first speech amplifier.
   B. Insert a high pass filter in the transmitter r.f. output.
   C. Alter the length of the transmission line by one quarter wavelength.
   D. Use double screened coaxial cable (triax) for the transmission line.

9. The meaning of the signal "QRW ZL1NP 3562?" is :

   A. "Please inform ZL1NP that I am calling him on 3562kHz"
   B. "Shall I inform ZL1NP that you are calling him on 3562kHz?"
   C. "Are you listening to ZL1NP on 3562kHz?"
   D. "Do you know that ZL1NP is calling you on 3562kHz?"

10. Which of the following usages of the phonetic alphabet would be most acceptable when spelling out the word MAGPUBS?

    A. MAYDAY ALPHA GEORGE PETER UNITED BAKER SUGAR
    B. MIKE ALPHA GOLF PAPA UNIFORM BRAVO SIERRA
    C. MELBOURNE ADELAIDE GRAFTON PAN UNIFORM BRISBANE SYDNEY
    D. MICHEGAN ATLANTA GEORGIA PENNSYLVANIA URGENCY BALTIMORE SEATTLE

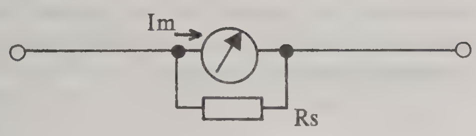
All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Test equipment & measurements.

The ammeter

Refer page 4.1.

To calculate Rs:



$$Rs = \frac{Im \times Rmeter}{I - Im}$$

where Im = f.s.d. of meter movement
I = current range required

Problem: a meter has 1mA f.s.d. and a resistance of 20Ω. Find the shunt resistance required to provide a range of 1A.

$$R = \frac{(1 \times 10^{-3}) \times 20}{(1000 \times 10^{-3}) - (1 \times 10^{-3})}$$

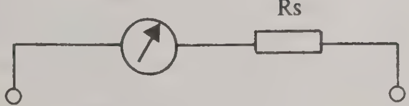
$$= \frac{20 \times 10^{-3}}{999 \times 10^{-3}}$$

$$= \underline{0.02\ \Omega}$$

The voltmeter

Refer page 4.1.

To calculate Rs:

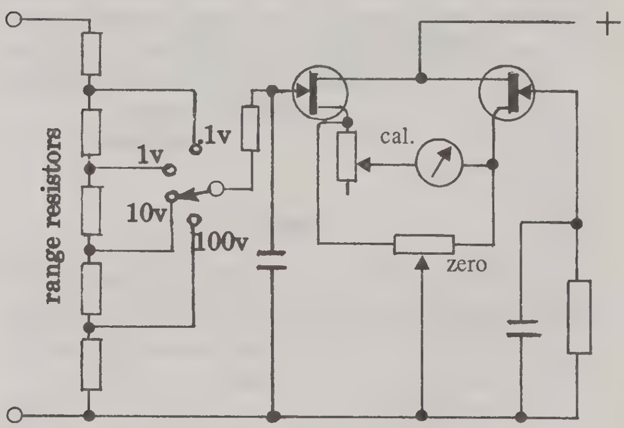


$$Rs = \frac{E}{Im} - R\ meter$$

where E = voltage range required
Im = f.s.d. meter movement

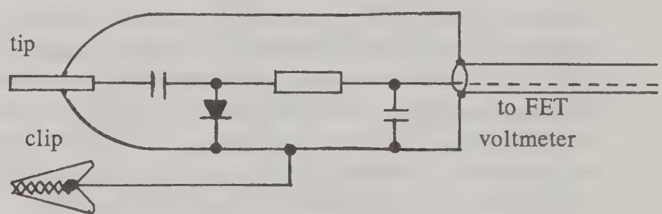
FET (or vacuum tube) voltmeter

Has high input resistance, allows both small and high voltage measurements with very little 'loading' to the circuit.



RF probe

Allows r.f. a.c. voltage measurements with FET voltmeter.



Probe eliminates capacity effects upon the circuit under test that would otherwise occur with ordinary long meter leads.

Thermocouple meter

Enables true r.m.s. a.c. current measurements of both a.f. and r.f.

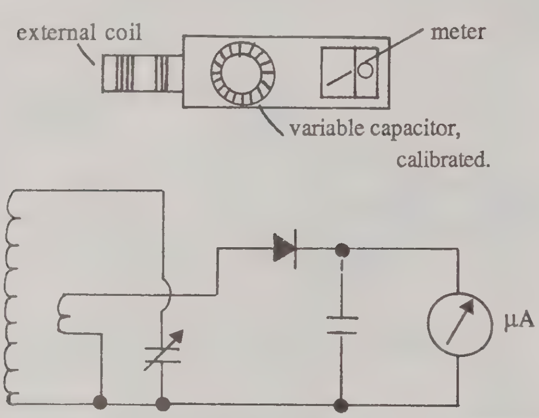
The current flows through a low-resistance heating element which warms a 'thermocouple', (a junction of two dissimilar metals which, when heated, generates a d.c. voltage). This d.c. voltage is applied to a normal moving coil meter movement.

Hotwire ammeter

Measurement of a.c. and d.c. currents. Not used much now because it can be inaccurate. Current flowing through a wire, held under tension, heats and expands the wire, moving a pointer as it does so.

Absorption wavemeter

A simple, but not highly accurate, means of measuring the frequency of an active tuned circuit. The external coil is placed near the circuit under test.



Grid-dip meter

Often incorporated with the absorption wavemeter, but measures frequency of a passive tuned circuit. It contains an oscillator, tuned by a variable capacitor. When the oscillator frequency is tuned to the resonant frequency of the circuit under test, energy will be absorbed from the oscillator, causing it to have less regeneration or feedback. The meter is usually in the grid, (or base), circuit where it will respond as a 'dip'.

Lecher lines

To measure wavelength, (or frequency), above about 100MHz.

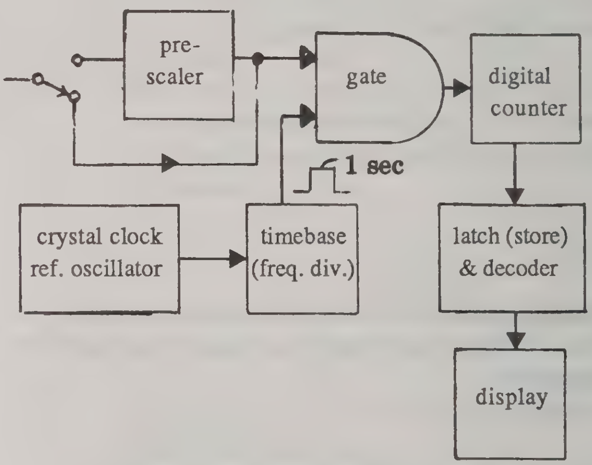
A pair of parallel lines, spaced about 25mm apart, forming a transmission line, has one end loosely coupled to the active tuned circuit being tested, such as a transmitter 'tank' circuit. A lamp is also loosely coupled to the 'tank' circuit. A 'shorting' bar is moved along the line and the distance between points of two minimums of brightness will be equal to one half the wavelength in the circuit under test. Frequency can then be calculated. Accuracy is not high, about 0.1%.

Hetrodyne frequency meter

Once very popular, a means of very accurately determining frequency. Contains a calibrated variable frequency oscillator, complete with a separate crystal reference oscillator. The unknown frequency is applied and mixes with the v.f.o. The v.f.o. is tuned to produce a 'beat', usually heard on a pair of headphones.

Digital frequency counter

A modern and accurate way to measure frequency by displaying the actual numerals of the frequency, and so allowing quick easy readings.



The signal to be measured is fed to the gate directly, or if too high in frequency, via a pre-scaler which divides it down by a set amount.

The gate 'opens' for 1 second exactly and the cycles that get through are counted, stored, and displayed in terms of frequency.

The 'time-base', applied to the other gate input, allows the opening of the gate.

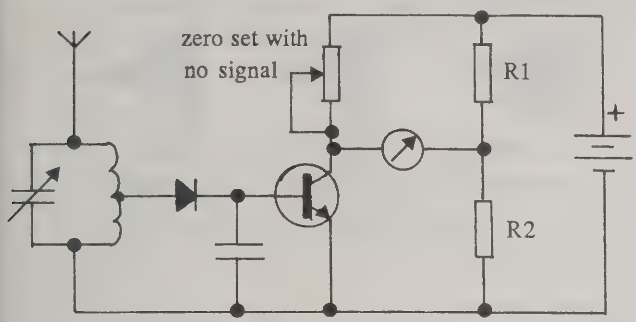
The crystal oscillator frequency is divided down to give the timebase of one second. Precise timebase accuracy depends therefore upon the accuracy of the crystal itself.

Dummy load

Provides a load of correct impedance for a transmitter under test instead of using an aerial. It is a pure resistance with no reactances and must be capable of handling the power output of the transmitter.

Field strength meter

Similar to the absorption wavemeter, but with a short aerial. It may have some amplification, and provides visual indication of a signal being radiated.

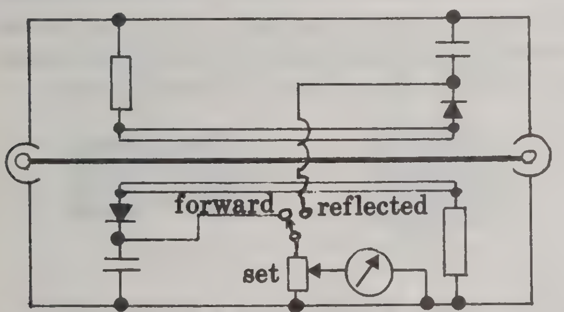


As the signal strength increases, the transistor is turned on, causing the collector voltage to fall in comparison with junction R1, R2. Meter will therefore read.

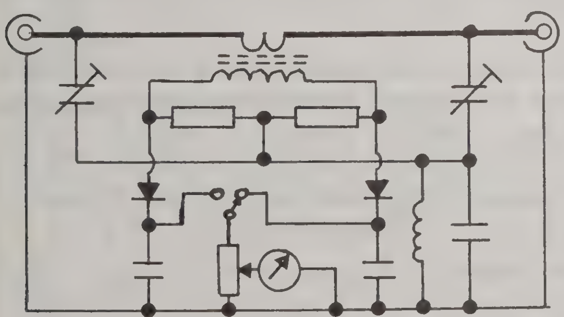
SWR bridge (reflectometer)

Indicates whether the transmission line is 'matched' to the aerial, by allowing the standing-wave-ratio to be determined. Placed in the transmission line, it distinguishes between forward and reflected waves. It also enables an aerial tuning unit to be adjusted when inserted in the line between transmitter and a.t.u.

In this circuit sampling 'loops' are capacitively coupled to the line. The meter reading is proportional to frequency:



The toridal transformer type is independant of frequency:



In both circuits, with the switch on 'forward', the 'set' control is adjusted for full-scale-deflection on meter. In the 'reflected' position the meter needle will fall and the s.w.r. read directly off the calibrated scale.

Impedance bridge

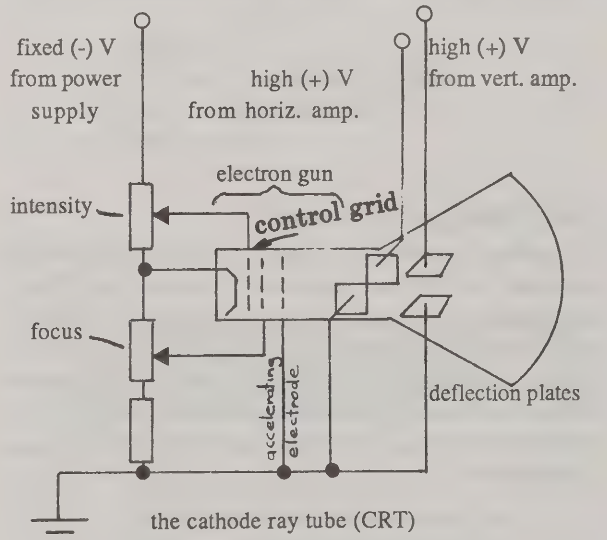
Useful for measuring unknown impedances such as the input impedance of a receiver on a particular frequency, or the impedance of an aerial. It has two sets of terminals, one to accept r.f., normally from a grid-dip meter, and the other to connect to the impedance under test.

Noise bridge

Another means of measuring the impedance of aerials. Contains a broadband noise generator and with an external receiver connected, "resistance" and "reactance" controls are adjusted for minimum noise. From the settings of the controls at this point, the amount of R and X can be read.

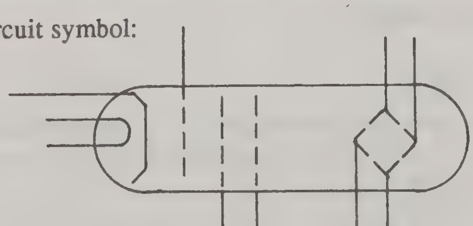
Oscilloscope

Enables the waveform of an a.f. or r.f. signal to be displayed on a screen called the cathode ray tube.

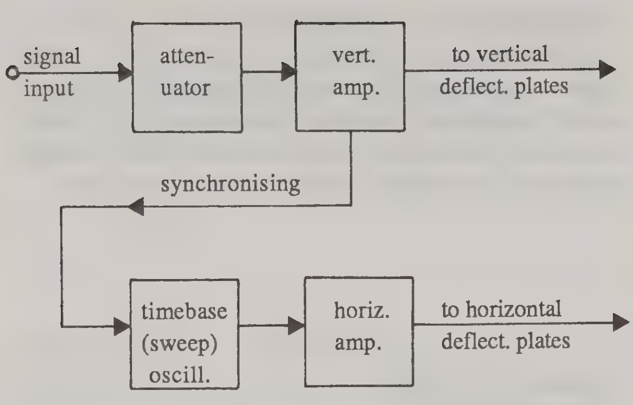


the cathode ray tube (CRT)

Circuit symbol:



The c.r.t. is a special valve with a screen area treated with a phosphor that glows, at the point of impact, when struck by an electron beam. The beam, produced by the electron gun, is directed by voltages on the deflection plates. The control grid has the most negative voltage on it.



the oscillocope

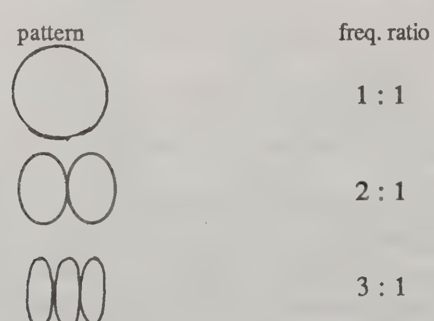
The amount of vertical deflection of the beam on the screen will depend upon the instantanous amplitude of the signal.

To make the beam move horizontally on the screen a large 'sawtooth' waveform, generated by a timebase oscillator, is fed to the horizontal plates. To ensure the image remains stationery on the screen, the frequency of the timebase is synchronised by the incoming signal.

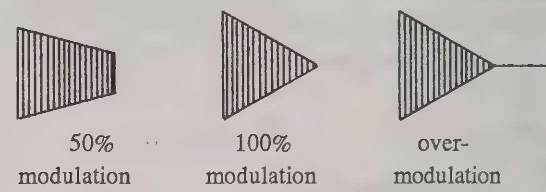
Oscilloscope uses

1. Voltage waveforms- signal is fed to the vertical input and the internal timebase is switched on. Peak, and peak-to-peak voltages, can be measured off a grid pattern superimposed on the outside of the screen. RMS values can be calculated from these, while the frequency can be determined by measurements and reference to a calibrated timebase. Any distortion in the waveform can often be seen also.

2. Lissajous figures- geometric patterns displayed when two sinusoidal voltages are applied to the vertical and horizontal deflecting plates. Useful for accurate frequency matching.

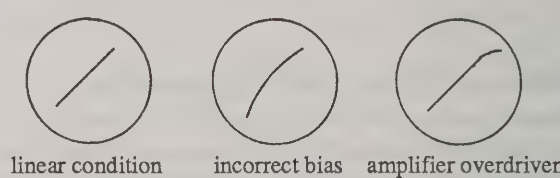


3. AM modulation- trapezoidal pattern, shows percentage of modulation and linearity of signal. The vertical plates are fed with a little r.f. from the 'tank' circuit while audio from the modulator is applied to the horizontal plates.



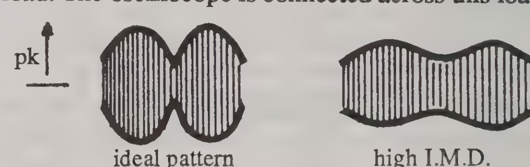
4. SSB checks

a). linearity- 45° method, a sinusoidal audio tone is fed into the transmitter. A signal is taken from the input of the transmitters linear power amplifier and another from the output. Each is passed through separate detector circuits and applied to the oscilloscopes vertical and horizontal plates respectively.



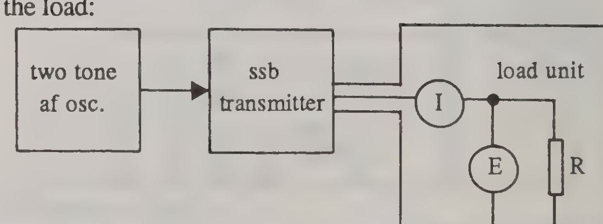
b). modulation- "two tone test" to show intermodulation-distortion-product, (I.M.D.), and measure peak envelope power. (PEP is the average power at the crest of the modulation cycle. Refer page 15.3).

Two non-harmonically related sinusoidal audio tones, of equal amplitude, are applied to the transmitter. The transmitter output is fed into a dummy load. The oscillocope is connected across this load.



$$P = \frac{E^2}{R} \qquad PEP = \frac{E^2\,(\text{rms at crest})}{R\,(\text{load})} = \frac{(0.707\,E_{pk})^2}{R_{load}}$$

PEP can also be determined by using an r.f. ammeter in series with the load, instead of the oscilloscope across the load:



$$PEP = 2 \times \text{mean power}$$
$$= 2 \times I^2 R \qquad \text{or} \qquad = 2 \times \frac{E^2}{R}$$

Assignment 22

1. A meter which has 100 mV developed across it when it is passing its maximum current of 0.01 A is required to measure a maximum current of 1.0A. The least error in the reading will occur if a resistor of -

    A. 0.1 ohms is added in parallel.
    B. 0.101 ohms is added in parallel.
    C. 0.11 ohms is added in parallel.
    D. 0.111 ohms is added in parallel.

2. Detector probes are used to measure RF voltages in circuits since they -

    A. Do not alter the resonance frequency of the circuit.
    B. Reduce feedback.
    C. Produce a minimum loading effect on the circuit.
    D. Do not absorb any power from the circuit.

3. An absorption wavemeter gives the most accurate indications when it is :

    A. Tightly coupled to the energy source.
    B. Lightly coupled to the energy source.
    C. Lightly coupled to the energy source via a highpass filter.
    D. Lightly coupled to the energy source via a lowpass filter.

4. The accuracy of a digital frequency meter is governed by -

    A. The timebase oscillator.
    B. The input impedance of the probe.
    C. Whether or not a pre-scaler is used.
    D. The method of buffering the display.

5. An in-line SWR meter operates by sensing:

    A. The characteristic impedance of the line.
    B. The transmitter output impedance.
    C. The line voltage and the line current.
    D. The square of the line voltage.

6. Which of the following terms is normally associated with oscilloscopes?

    A. Clemens transformer.
    B. Pulse transformer.
    C. Sweep generator.
    D. Pawsey stub.

7. Using a known 40 Hz signal and an oscilloscope to set an audio oscillator to 50 Hz; which of the following patterns will appear on the screen when the frequencies are equal?

    A. One loop.
    B. Two loops one above the other.
    C. Two loops side by side.
    D. One trapezoid.

8. To calculate the maximum peak envelope power of a voice modulated SSB suppressed carrier transmitter's output which of the following is used?

    A. Instantaneous peak voltage.
    B. RMS value of the voltage waveform.
    C. RMS value of the peak r.f. voltage.
    D. Mean value of the voltage waveform.

All questions in this assignment are reproduced from past examination papers courtesy of RFS.

Regulations

In this lesson extracts are reprinted from:

The Telecommunications Act 1987 incorporating changes made by the Telecommunications Amendment Act 1988.

The Radio Regulations 1987 incorporating changes up to and including Amendment No.5 dated 10 July 1989.

These <u>are not</u> the complete regulations or Act but are those more closely dealing with amateur radio. The complete Regulations and Act, as well as any subsequent amendments, are obtainable from the Government Bookshop.

Further general information written by the author has been derived from:

The N.Z. Radio Frequency Service Pamphlet RT4, Edition 2, amended June 1989,

The "Amateur Operator's Certificate: Information For Candidates Wishing To Sit Section B" booklet produced by the Auckland office of the R.F.S.

Telecommunications Act extracts

PART I

2. Interpretations- (1) In this part of this Act, unless the context otherwise requires,-

"Fixed radio station" means radio apparatus comprising transmitters or receivers, or a combination of transmitters and receivers, installed at a fixed location, for the purposes of carrying on a radiocommunication service:

"Minister" means the Minister of Commerce:

"Radiocommunication" means any transmission, emission, or reception of signs, signals, writing, images, sounds, or intelligence of any nature by electromagnetic waves of frequencies between 9 kilohertz and 3,000 gigahertz, propagated in space without artificial guide:

"Radio apparatus" means any apparatus intended for the purpose of effecting radiocommunication, whether by transmission or reception, or both:

"Radio frequency" means electromagnetic waves of frequencies between 9 kilohertz and 3,000 gigahertz, propagated in space without artificial guide:

PART II

21. Interpretation- In this Part of this Act, unless the context otherwise requires,-

"Court" means a District Court:

"Interfering equipment" means any apparatus or equipment of any kind (whether radio apparatus or equipment or not) that may generate electric waves (being radio frequency energy) likely to interfere with radiocommunications; and includes an electric power line within the meaning of the Public Works Act 1981:

"Registrar" means the Registrar of a Court; and includes any Deputy Registrar:

"Secretary" means the Secretary of the Ministry of Commerce and includes those officers delegated by him for the performance of specific duties. *(Authors note - amended as per Auckland RFS office booklet.)*

23. Licensing of radio apparatus -

(2) The Secretary may, in accordance with regulations made under this Part of this Act, grant licences for the installation, operation, or use of radio apparatus within the territorial limits of New Zealand, or on any New Zealand ship, or on any aircraft registered in New Zealand.

(3) Subject to any such regulations, every such licence shall be in such form and for such period, and shall contain such terms, conditions, and restrictions as the Secretary thinks fit.

(4) Where, pursuant to regulations made under this Part of this Act, the installation, operation, or use of radio apparatus of any class or classes is prohibited, except pursuant to a licence or licences granted under this Part of this Act, any person who erects, constructs, establishes, maintains, uses, or is in possession of any radio apparatus of that class or those classes capable of transmitting radiocommunications otherwise than pursuant to, or in conformity with, the terms and conditions of a licence issued under this section, commits an offence against this Part of this Act.

(5) Where, pursuant to regulations made under

this Part of this Act, the installation, operation or use of radio apparatus of any class or classes is prohibited, except pursuant to a licence or licences granted under this Part of this Act, any person who is in possession of any radio apparatus of that class or those classes capable of receiving radiocommunications otherwise than pursuant to, and in conformity with, the terms and conditions of a licence issued under this section, commits an offence against this Part of this Act.

(6) The occupier of any premises on which is situated any radio apparatus capable of transmitting radiocommunications shall be presumed to have erected, constructed, established, maintained, used, and to be in possession of the radio apparatus unless and until the contrary is proved.

(7) The occupier of any premises on which is situated any radio apparatus capable of receiving radiocommunications shall be presumed to be in possession of the apparatus unless and until the contrary is proved.

(8) Any radio apparatus shall for the purposes of this section be deemed to be, and to remain, capable of transmitting or, as the case may be, receiving radiocommunications, notwithstanding that, without having been completely dismantled, or rendered inoperative to the satisfaction of the Secretary, it may be temporarily incapable of doing so.

26. Powers to obtain documents and radio apparatus-

(1) Subject to this section, any officer or employee of the Public Service authorised in writing by the Secretary for the purpose, or a constable, may, for the purpose of ascertaining or establishing whether any person has committed or is committing an offence against this Part of this Act or against any regulations made thereunder, at any time in the day or night, enter upon and search any premises, building, aircraft, ship, carriage, vehicle, box, receptacle, or place and-

(a) Inspect, remove and take copies of any documents or extracts therefrom, in the possession of, or under the control of, any person; and

(b) Inspect and remove any radio apparatus or interfering equipment in the possession of, or under the control of, any person.

(2) No person shall exercise the powers conferred by subsection (1) of this section unless the person obtains a warrant....

27. Penalties-

(1) Every person who commits an offence against this Part of this Act or against any regulations made under this Part of this Act is liable on summary conviction-

(a) In the case of a person other than a body corporate, to a fine not exceeding $20,000; and

(b) In the case of a body corporate, to a fine not exceeding $100,000.

(2) Where, in any proceedings under this section, the Court finds that a person has committed an offence against this Part of this Act, the Court may order any radio apparatus or interfering equipment (being the property of a person convicted under subsection (1) of this section) in relation to which the offence has been committed to be forfeited.

Radio Regulation extracts

2. Interpretation- In these regulations, unless the context otherwise requires,-

"The Act" means the Telecommunications Act 1987:

"Apparatus" means radio apparatus:

"International Radio Regulations" means the Radio Regulations annexed to the International Telecommunication Convention, done at Nairobi in 1982, and includes any revisions of, or any regulations made in amendment to, or substitution for, such regulations:

3. Applicaton of regulations- Except as otherwise provided in these regulations, these regulations shall apply to apparatus -

(a) within the territorial limits of New Zealand:

(b) On any New Zealand ship:

(c) On any aircraft registered in New Zealand.

5. Secretary may operate apparatus- Notwithstanding anything in these regulations, the Secretary may, for the purposes of the administration of these regulations, install, operate, and use such apparatus, in such manner, as the Secretary thinks fit.

PART I

6. Installation, operation and use of certain apparatus prohibited-

(1) Subject to regulation 6A of these regulations, the installation, operation and use of all apparatus for the transmission or reception of radiocommunication is hereby prohibited except pursuant to a written licence granted by the Secretary.

(2) Nothing in subclause (1) of this regulation shall prohibit any person in distress from using any means at that person's disposal to attract attention, indicate the person's position, and obtain assistance.

6A. Exemptions from licensing-

(1) The Secretary may, by notice in writing to the holder of the apparatus or by notice in the *Gazette*, exempt certain radio apparatus, or class or classes of radio apparatus, from the requirement to be licensed under regulation 6 (1) of these regulations, where the Secretary is satisfied that a licence is not required for the efficient and effective management of the radio frequency spectrum.

(2) Every exemption granted under subclause (1) of this regulation shall be subject to such terms, conditions, and restrictions as the Secretary sees fit.

6B. Revocation of exemptions- The Secretary may from time to time, by notice in writing to the holder of the apparatus, or by notice in the *Gazette*, revoke any exemption or exemptions granted under regulation 6A of these regulations.

7. Application for licence-

(1) Any person desiring to obtain such a licence shall make applicaton in writing in such form as shall be required by the Secretary.

(2) Every such application shall be accompanied by such fee as is prescribed by these regulations in respect of such application.

(3) Every such application shall be sent or delivered to the Secretary at such address as shall be specified by the Secretary for the purpose.

9. Proof of information- The Secretary may require, in such form as the Secretary shall specify, proof of any information supplied by an applicant.

10. Grant of licence-

(1) Subject to this regulation, the Secretary may, in respect of an application made under regulation 7 of these regulations, grant a licence or decline to do so.

(3) Without limiting any other provision of the Act or these regulations, every licence granted under this regulation shall specify-

(a) The name of the person to whom it is granted; and

(b) The apparatus to which it applies; and

(c) The purpose for which the apparatus may be used pursuant to the licence.

14. Licences to be subject to terms, conditions, and restrictions-

(1) Except as may be provided therein, every licence granted under this Part of these regulations shall be subject to the terms, conditons, and restrictions specified in the First Schedule to these regulations.

(2) Nothing in subclause (1) of this regulation shall limit the power of the Secretary, under section 23 (3) of the Act, to include in any licence such terms, conditions and restrictions as the Secretary thinks fit.

15. Revocation or modification of licence-

The Secretary may from time to time-

(a) By notice in writing to the licensee, revoke any licence granted under this Part of these regulations or modify the terms, conditions, or restrictions which apply thereto; or

(b) By notice in the *Gazette*, revoke any licence or licences or any class or classes of licences granted under this Part of these regulations or modify the terms, conditions, or restrictions which apply thereto.

16. Period of validity of licence-

(1) Subject to subclause (2) of this regulation each licence granted under this Part of these regulations shall be valid for such period as shall be specified therein and shall then expire.

(2) The Secretary may from time to time revalidate any such licence upon the payment of the fee prescribed by these regulations for the purpose.

PART III

24. Privacy of radiocommunications- Except as may be authorised under these regulations or under any licence granted pursuant to these regulations, no person who receives any radiocommunication not intended for that person shall-

(a) Make use of the radiocommunication or any information derived therefrom:

(b) Reproduce or cause or permit to be reproduced the radiocommunication or information derived therefrom:

(c) Disclose the fact of the existence of the radiocommunication.

PART IV

25. Examinations as to competence- The Secretary shall, from time to time, provide for the conduct, by persons authorised by the Secretary to do so, of the examinations prescribed in these regulations to determine the competence of persons wishing to hold certificates of competency in the operation of apparatus.

26. Classes of certificates-

(1) The Secretary may, from time to time, grant to any person who has successfully completed an examination prescribed by these regulations, or to any other person who in the opinion of the Secretary meets the requirements for the granting of a certificate, a certificate of competency of a class specified in subclause (2) of this regulation.

(2) The classes of certificates of competency which may be granted under subclause (1) of this regulations are-

(c) General amateur operator certificate:

(d) Limited amateur operator certificate:

(e) Novice amateur operator certificate:

27. Examinations prescribed- The examinations prescribed in respect of the classes of certificate specified in regulation 26 (2) of these regulations shall be as specified in the Second Schedule to these regulations.

28. Form of certificate- Any certificate issued under this Part of these regulations shall be in such form and subject to such conditions, directions, or rules, as the Secretary may, from time to time, prescribe for the purpose.

29. Terms, conditions, and restrictions in connection with certificate- The Secretary may, in connection with any certificate, impose such terms, conditions, and restrictions, not inconsistent with the Act or these regulations, as the Secretary thinks fit.

30. Secretary may refuse to grant application for an operator certificate- The Secretary may, in the Secretary's discretion, refuse to grant an application for any class of operator certificate.

31. Recognition of foreign operator certificates- The Secretary may from time to time, in the Secretary's discretion, recognise as the equivalent of any certificate issued under these regulations any certificate of similar class issued in another country in accordance with the laws of that country.

32. Conditions for the conduct of examinations- The Secretary may from time to time, by notice in the *Gazette*, prescribe the conditions for the conduct of any examination conducted under these regulations.

33. Re-examination-

(1) Where the Secretary considers that it is necessary or desirable in the public interest to do so, the Secretary may require any person to whom any class of operator certificate under these regulations has been issued to subject himself or herself for re-examination in any or all of the subject required for examination for the class of certificate concerned.

(2) Where any person fails to submit himself or herself for re-examination in accordance with this regulation when so required by the secretary, or fails to qualify at the re-examination, the certificate or authorisation issued to that person may be suspended or revoked for such period as the Secretary, in the Secretary's discretion, shall determine.

34. Recount of marks awarded-

(1) In circumstances in which any such action appears to the Secretary to be desirable, the Secretary may approve a recount being made of the marks awarded to a candidate in respect of any written examination prescribed by these regulations.

(2) The fee in respect of each paper for which a recount of marks is undertaken shall be that prescribed in the Third Schedule to these regulations.

PART V

36. Limits of intensity for interfering equipment-

(1) The Secretary may from time to time, by notice in the *Gazette*, prescribe limits within which radio frequency energy produced by interfering equipment of the class or classes specified in the order must be suppressed.

(2) Except as otherwise provided in this Part of these regulations, no person shall install, use, sell, or manufacture interfering equipment to which a notice under subclause (1) of this regulation applies, which does not comply with the notice.

(5) Every person who contravenes subclause (2) ...... of this regulation commits an offence.

PART VII

43. Fees-

(1) The fees (inclusive of goods and services tax) payable in respect of applications made and licences and certificates issued under these regulations shall be as specified in the Third Schedule to these regulations.

(2) The Secretary may waive, in whole or in part, any fee payable under these regulations.

FIRST SCHEDULE

1. Compliance with technical specifications- The licensee shall ensure that the apparatus to which the licence relates complies with any technical specifications relating to such apparatus as may be issued from time to time by the Secretary.

2. Compliance with International Radio Regulations- The licensee shall comply with the International Radio Regulations insofar as they apply to the class of licence held by the licensee.

3. Limits of use of apparatus- The licensee shall not take part in any radiocommunication other than as specified in the licence.

4. Licensee personally responsible for observance of terms, etc., of licence- Notwithstanding any approval that may from time to time be given by the Secretary for any person other than the licensee to operate the apparatus to which the licence relates, the licensee shall be personally responsible for the observance of all terms, conditions, and restrictions which apply to the licence as if the apparatus were operated by the licensee.

5. Notification of change of address- When a licence is expressed to apply to apparatus at a particular address, the licensee shall, within 7 days of removing the apparatus from the address, notify the Secretary of the removal.

6. Apparatus not to be operated in manner which endangers other radiocommuncations- The licensee shall not operate the apparatus to which the licence relates in a manner which endangers the functioning of radionavigation apparatus, or seriously degrades, obstructs, or repeatedly interrupts radiocommunications operating in accordance with these regulations.

7. Licensee to comply with directions- The licensee shall comply with any directions relating to the use of the apparatus to which the licence relates given to the licensee by the Secretary or any person authorised by the Secretary to give such direction on the Secretary's behalf.

8. Allocation of frequency not to confer monopoly- The allocation of a frequency to a licensee shall not be held to confer upon the licensee a monopoly of the use of that frequency.

9. Operator of apparatus to hold valid operator certificate- Except as otherwise provided herein, the apparatus to which the licence relates shall not be operated by any person who is not the holder of a valid certificate of the required class, or an authorisation issued, or a certificate recognised by the Secretary.

10. Callsigns- The callsign of the apparatus to which the licence relates shall be the callsign shown on the licence.

11. Use of apparatus for impersonation, etc.- Neither the licensee nor any other person transmitting from the apparatus to which the licence relates shall, by means of the apparatus to which the licence relates, impersonate any other person, or pass off that apparatus to be other apparatus, or improperly use the callsign allocated to other apparatus.

12. False or misleading communication- Neither the licensee nor any other person transmitting from the apparatus to which the licence relates shall cause or permit the transmission of any radio communication of a false, fictitious, or misleading character, and in particular but without limiting the generality of the foregoing, cause or permit to be transmitted any false or deceptive distress signal or distress call.

13. Licence to be available for inspection- The licensee shall cause the licence to be available at all times for inspection by an authorised officer.

14. Dismantling of apparatus when contravention has taken place- Where an authorised officer, being of the opinion that a contravention of the Act or the regulations (whether by a breach of any of these terms, conditions, and restrictions or otherwise) has taken place in respect of the apparatus to which the licence relates, requires that operation of the apparatus shall cease, or that the apparatus shall be dismantled, or that the apparatus or any part thereof shall be surrendered to the officer or rendered inoperative, the licensee shall comply with the requirement.

SECOND SCHEDULE

Part C- *General Amateur Operator Certificate*
To qualify for a general amateur operator certificate, a candidate shall be required to pass-

(a) A written examination prescribed by the Secretary for the purpose, in the principles of electricity, radio telegraphy, and radiotelephony, and in the adjustment and operation of apparatus used by amateur radio operators; and

(b) A written examination, prescribed by the Secretary, in -

(i) The law relating to the installation, operation and use of apparatus used by amateur radio operators; and

(ii) The operating procedures, service codes, and abbreviations applicable to such apparatus; and

(c) A morse operating test, prescribed by the Secretary, both sending and receiving, at a speed of 12 words per minute.

Part D- *Limited Amateur Operator Certificate*
To qualify for a limited amateur operator certificate, a candidate shall be required to pass the written examinations prescribed in respect of the general amateur operator certificate but shall not be required to pass a morse operating test.

Part E- *Novice Amateur Operator Certificate*
To qualify for a novice amateur operator certificate, a candidate shall be required to-

(a) Complete the written examinations prescribed in respect of the general amateur operator certificate to a standard determined by the Secretary for the purpose, being a standard no greater than the standard required in respect of the general amateur operator certificate; and

(b) Pass a morse operating test, both sending and receiving, at a speed of 6 words per minute.

THIRD SCHEDULE

Part A- *Licences issued under Part I of these regulations.*
Licence Type- Amateur, Initial licence fee per annum or part thereof = $40.50
Annual Renewal Fee = $40.50

Part C- *Certificates of competency issued under Part IV of these regulations.*
Examination fee for each certificate type-

General Amateur =	$30.80
Limited Amateur =	$20.90
Novice Amateur =	$30.80

Recount of marks in respect of any class of certificate = $ 9.90

Duplicate copy of certificate $ 9.90

Miscellaneous

The amateur radio service is defined as a radiocommunication service for the purpose of self training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorised persons interested in radio technique solely with a personal aim and without pecuniary interest.

All radiocommunications between licensed amateur operators must be limited to messages pertaining to the amateur radio service or be of a personal character such that, by reason of their unimportance, use of commercial circuits would not be justified; use of amateur radio must not be used to circumvent normal telecommunications circuits.

Except in the case of emergency, see also Radio Regulations 6 (2), or where otherwise approved by the Secretary, amateur operators may only communicate with other licensed amateur operators.

The amateur licence shall permit the use of both transmitting apparatus and receiving apparatus.

The licensee shall transmit its callsign as frequently as practicable, and in any event at least once in each hour during the course of transmissions.

Power permitted- The power permitted to be used in transmitting apparatus by an amateur licensee shall be as follows:

(a) For a novice licensee the radio frequency output shall not exceed 10 watts mean power output, except where the power output varies with the modulation in which case the radio frequency output shall not exceed 30 watts peak envelope power.

(b) For a limited or general licensee the radio frequency output shall not exceed 120 watts mean power output, except where the power output varies with the modulation, in which case the radio frequency output shall not exceed 400 watts peak envelope power.

Power measurements are taken at the output terminals of the final amplifying stage, including any separately connected amplifier, supplying the power to the aerial.

The expression "mean power" means the average power supplied to the antenna transmission line by a transmitter during an interval of time sufficiently long compared with the lowest frequency encountered in the modulation taken under normal operating conditions.

The expression "peak envelope power" means the average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle at the crest of the modulation envelope taken under normal operating conditions.

At any amateur station employing equipment capable of exceeding the permissible power levels the licensee is obliged to fit a power measuring device which will indicate, visibly or audibly, when the levels are exceeded.

Logkeeping- The decision as to whether a log will be kept at a particular amateur station is a decision which rests with the licensee except where operation in the 50.00 - 50.15MHz 6m sub-band has been approved during hours of television programme hours. The author suggests that the log show the hours during which the station is in operation, the time of each transmission, the class of emission, the station called, and the power and the frequency used.

Third party traffic- The expression "Third Party" means any person, or organisation not currently licensed amateurs.

Licensees of amateur radio apparatus shall not use, or permit to be used any such apparatus for the transmission of international communications for any third party unless a bilateral agreement has been concluded between New Zealand and the overseas administration concerned.

Within New Zealand licensed amateurs may:

(i) Pass brief personal messages on behalf of a third party provided no tolls, fees or other consideration is received or collected by the licensee.

(ii) Permit a third party to use their amateur radio apparatus under their direct supervision provided the amateur licensee completes the calling and signing off procedures and operates the controls of the apparatus.

Visitors- A visitor being the holder of an amateur licence granted by an overseas administration can be issued with an authorisation to use amateur radio apparatus in New Zealand where a reciprocal agreement has been concluded with the overseas administration. The visitor is given a callsign from the ZLØ series.

Any visitor holding a recognised Commonwealth amateur certificate or licence may be issued with a short-term amateur licence, having a callsign from the ZLØ series, for the duration of the visit.

A visitor who, in the country in which he is normally resident, is the holder of an amateur licence or certificate may operate on a licenced NZ amateur's radio apparatus under the direct supervision of the licensee. If the visitor does not hold an authorisation or short-term licence the callsign of the NZ licensee must be used.

Any visitor, holding a current amateur licence issued by an overseas administration, may operate amateur radio apparatus in NZ on 144MHz and above for a period not exceeding four weeks using his "home callsign/ZL". In such cases, no written authorisation is needed.

Assignment 23.

1. Under what circumstances may stations of the amateur service communicate with stations not of the amateur service?

   A. During an emergency.
   B. Under no circumstances.
   C. When authorised by NZART.
   D. When called by a non-amateur station.

2. What is the maximum power permitted for an amateur station?

   A. 200 watts.
   B. 100 watts.
   C. 400 watts.
   D. 50 watts.

3. With respect to two-way contacts between two amateur stations, the term "third Party" refers to:

   A. A person other than the two amateur operators.
   B. A third amateur operator joining the contact.
   C. An unlicenced operator supervised by an Amateur Operator.
   D. An operator on the frequency, unaware that it is in use.

4. In the absence of an amateur operator from his home station:

   A. The station may be used by his family.
   B. The station may not be used by any unlicensed person.
   C. He may maintain communication with his family if the station callsign is used by both stations.
   D. He must obtain a separate mobile licence to communicate with his family at the house station.

5. With respect to the amateur service an amateur radio operator using his station "without pecuniary interest" must not:

   A. Pay more than the prescribed rate of interest on money borrowed to establish his station.
   B. Make profit or financial gain by the reception and transmission of messages from his station.
   C. Make profit or financial gain by selling equipment used in amateur stations.
   D. Be engaged in a vocation in radio, electronics or communications.

6. When a visiting novice operator operates the station of an operator holding an amateur operators general certificate the novice operator should use:

   A. The station owner's callsign.
   B. His own callsign.
   C. Both callsigns.
   D. The station owner's callsign with the suffix "/N".

7. An amateur radio operator is asked by a person to pass a business message to another amateur station. The amateur should:

   A. Agree to handle the message for the equivalent telegraph rate.
   B. Agree to handle the message, but accept no payment.
   C. Refuse to handle the message under any circumstance.
   D. Handle the message, but warn the person he is liable for any penalty.

8. The payment of a licence fee validates a station licence for what period?

   A. One year only.
   B. Two years only.
   C. Five years only.
   D. Any period.

9. The issue of an amateur radio station licence authorises the use of:

   A. A transmitter.
   B. A TV receiver.
   C. Both transmitting and receiving apparatus.
   D. Maritime mobile VHF equipment.

10. "Harmful interference" means:

    A. A high antenna mast without marker lights.
    B. The loudspeaker is turned up too loud.
    C. Radiation or emission which obstructs or interrupts other licenced radio services.
    D. Interference caused by a station of the secondary service.

All questions in this assignment are reproduced from Section B of the March 1987 examination paper courtesy of RFS.

LESSON 24

Trial test

This test is half the 'real' thing. You are allowed to be nervous and even allowed to make mistakes, just this time!

The test will consist of:

Section A- theory, 40 multi-choice
Section B- regulations, 15 multi-choice
Time allowed- 90 minutes

(A set of questions for this test has deliberately not been prepared for obvious reasons).

Tutors- select questions from past papers or from this course. An answer sheet for is set out over on the next page. The papers may be marked 'on-the-spot' before the students go home. Prior to the test prepare a cardboard template the same size as the answer sheet. Cut out square holes corresponding to each questions correct answer. Use by placing the template over the students completed answer sheet and the correctly ticked answers will be exposed.

Readers- give yourself a test. For section A try say every odd numbered or every even numbered question in Appendix II. By using these the answers can be checked. But no cheating!

To help convert your results into a percentage:

Section A -

11 = 28%	21 = 53%	31 = 78%
12 = 30%	22 = 55%	32 = 80%
13 = 33%	23 = 58%	33 = 83%
14 = 35%	24 = 60%	34 = 85%
15 = 38%	25 = 63%	35 = 88%
16 = 40%	26 = 65%	36 = 90%
17 = 43%	27 = 68%	37 = 93%
18 = 45%	28 = 70%	38 = 95%
19 = 48%	29 = 73%	39 = 98%
20 = 50%	30 = 75%	40 = 100%

Section B -

4 = 27%	8 = 53%	12 = 80%
5 = 33%	9 = 60%	13 = 87%
6 = 40%	10 = 67%	14 = 93%
7 = 47%	11 = 73%	15 = 100%

Instructions for candidates

Time allowed: 90 minutes

1. The examination is in two parts:
   Section A: Theory
   Section B: Regulations

2. To obtain a pass in Section A the candidate must answer correctly 20 of the 40 multiple-choice questions for the equivalent of a General or Limited Grade, or 12 of the 40 for the equivalent of a Novice grade.
   To obtain a pass in Section B of this test, candidates for all grades must answer correctly 8 of the 15 multiple-choice questions.

3. All questions should be attempted.

4. Use the answer sheet over on the next page for Sections A and B.

5. For each question in Section A and B only one of the suggested answers is correct. Place a tick in the appropriate box (A, B, C, or D) to indicate which answer is correct.

6. Any question which shows more than one box ticked shall be deemed to be incorrect and attract no marks.

7. If, after reassessment of the paper, you wish to change one of the answers, place a note in the margin of the answer paper to this effect and mark the original choice with an oblique stroke, e.g.,

(changed)

8. The question paper may be retained by the candidate.

Assignment 24

Go over the test paper. Try to see where you have gone wrong. This paper will be discussed in Lesson 25. Meanwhile do a little revision.

Answer sheet

Name ______________________________

Section A-

1.	A	B	C	D
2.	A	B	C	D
3.	A	B	C	D
4.	A	B	C	D
5.	A	B	C	D
6.	A	B	C	D
7.	A	B	C	D
8.	A	B	C	D
9.	A	B	C	D
10.	A	B	C	D
11.	A	B	C	D
12.	A	B	C	D
13.	A	B	C	D
14.	A	B	C	D
15.	A	B	C	D
16.	A	B	C	D
17.	A	B	C	D
18.	A	B	C	D
19.	A	B	C	D
20.	A	B	C	D
21.	A	B	C	D
22.	A	B	C	D
23.	A	B	C	D
24.	A	B	C	D
25.	A	B	C	D
26.	A	B	C	D
27.	A	B	C	D
28.	A	B	C	D
29.	A	B	C	D
30.	A	B	C	D
31.	A	B	C	D
32.	A	B	C	D
33.	A	B	C	D
34.	A	B	C	D
35.	A	B	C	D
36.	A	B	C	D
37.	A	B	C	D
38.	A	B	C	D
39.	A	B	C	D
40.	A	B	C	D

Section B-

1.	A	B	C	D
2.	A	B	C	D
3.	A	B	C	D
4.	A	B	C	D
5.	A	B	C	D
6.	A	B	C	D
7.	A	B	C	D
8.	A	B	C	D
9.	A	B	C	D
10.	A	B	C	D
11.	A	B	C	D
12.	A	B	C	D
13.	A	B	C	D
14.	A	B	C	D
15.	A	B	C	D

LESSON 25

Test review

Go over the test held in lesson 24.

Discuss any problem areas or questions from past papers that are puzzling.

Assignment 25

All the best for the exam!

LESSON 26

Examination review

For the brave, lets go over the examination paper.

Assignment 26

See you on the air!

APPENDIX I

Syllabus, RFS offices, timetable

Syllabus

The Amateur Radio examination syllabus presented here is reprinted from the New Zealand Radio Frequency Service pamphlet RT4, Edition 2, amended June 1989.

Electrical principles-
Sources of EMF. Physical and electrical properties of resistors, capacitors and inductors. Electrical properties of resistors, capacitors and inductors both individually and in combination when connected to a source of alternating or direct voltage and the effect of varying the frequency of the alternating voltage on these properties. The relationship between peak, RMS and mean values of a waveform.

The use of Ohm's Law to relate voltage to current flowing through an impedance and the determination of power dissipated in that impedance. The electrical properties of resonant circuits both coupled and individual. Schematic diagram symbols.

Thermionic valves and semi-conductor devices-
General construction, operation and electrical characteristics of valves and semi-conductor devices. Biasing methods. Basic circuit configurations and variations involving input impedance, output impedance and gain. Amplifier classification. Positive feedback and oscillator types. Frequency synthesis. Gates and diode switching. Power rectification, smoothing and voltage regulation. Distortion, harmonics, negative feedback, push-pull operation.

Receivers-
Principles of operation and factors influencing the performance of receivers intended to receive the permitted modes of emission on any frequency available to the amateur operator.

Propagation-
The means of propagating radio waves of any frequency available to the amateur operator. Factors which influence propagation conditions.

Antennas-
Characteristics of common types of antenna both directional and non-directional. Transmission lines. Standing wave patterns and standing wave ratios. Coupling of transmitters to transmission lines and transmission lines to antennas.

Transmitters-
Methods of generating and increasing the level of radio frequency energy using any of the permitted modes of emission on any frequency available to the amateur. Technical characteristics of the various modes of emission available to the amateur operator. Transmitter adjustments. Microphones.

Interference-
Frequency stability. Means of preventing or reducing to acceptable levels unwanted emissions. Means of eliminating or reducing interference to nearby electronic equipment.

Measurements-
Measuring instruments. Measurement of frequency, power, alternating and direct voltage and current, resistance, standing waves. Use of the oscilloscope.

Safety-
Safety precautions and resuscitation practices.

R.F.S. offices

New Zealand Radio Frequency Service offices for Amateur Operator Certificate of Competency enquires and for all amateur radio licensing matters:

Head Office-
Bowen State Building, Bowen Street, Wellington.
P.O. Box 2847, Wellington.
Ph: (04) 732 200.

Whangarei-
National Mutual Building, Rathbone Street, Whangarei.
P.O. Box 449, Whangarei.
Ph: (089) 488 491

Auckland-
Altos House, Cnr Newton Rd and Abbey St, Newton.
P.O. Box 68-217, Newton, Auckland.
Ph. (09) 788 537

Hamilton-
512 Grey Street, Hamilton.
P.O. Box 982, Hamilton.
Ph. (071) 387 150

Rotorua-
Government Life Building, Haupapa Street, Rotorua.
P.O. Box 847, Rotorua.
Ph. (073) 460 370

Gisborne-
Post Building, Grey Street, Gisborne.
P.O. Box 339, Gisborne.
Ph. (079) 78 424

Napier-
First floor, Manchester Unity Buiding, Corner Kennedy Road and Nuffield Avenue, Marewa, Napier.
P.O. Box 4162, Marewa, Napier.
Ph. (070) 435 829

New Plymouth-
N.Z. Post Building, Currie Street, New Plymouth.
P.O. Box 217, New Plymouth.
Ph. (067) 88 138

Palmerston North-
328-330 Broadway Avenue, Palmerston North.
P.O. Box 5063, Palmerston North.
Ph. (063) 66 710

Wellington-
70 Bloomfield Terrace, Lower Hutt.
P.O. Box 31-433, Lower Hutt.
Ph. (04) 665 537

Nelson-
First Floor, Farm Products, 42 Halifax Street, Nelson.
P.O. Box 997, Nelson.
Ph. (054) 82 446

Greymouth-
Telephone Exchange Building, Tainui St, Greymouth.
P.O. Box 442, Greymouth.
Ph. (027) 80 312

Christchurch-
St. Elmo Courts, 47 Hereford Street, Christchurch.
P.O. Box 1800, Christchurch.
Ph. (03) 654 401

Timaru-
First Floor, Railway Station, Station Street, Timaru.
P.O. Box 589, Timaru.
Ph. (056) 48 120

Dunedin-
12 Hanover Street, Dunedin.
P.O. Box 5647, Moray Place, Dunedin.
Ph. (024) 771 125

Invercargill-
13 Esk Street, Invercargill.
P.O. Box 247, Invercargill.
Ph. (021) 44 952

Course timetable

A suggested programme for Tuesday classes leading up to the September 1990 examination:

20.2.90	Lesson 1. Introduction		
27.2		2. Maths and electricity	
6.3		3. Direct current	
13.3		4. Basic measurements	
20.3		5. Inductance and capacitance	
27.3		6. Timing circuits	
3.4		7. Alternating current	
10.4		8. Resonance	
17.4	*Easter Break*		
24.4		9. Semiconductor 1	
1.5		10. Semiconductor 2	
8.5	*May School Holidays*		
15.5	*May School Holidays*		
22.5		11. Semiconductor 3	
29.5		12. FET's, thermionics	
5.6		13. Mains operated power supplies	
12.6		14. Oscillators	
19.6		15. Transmitter basics	
26.6		16. Transmitter details	
3.7		17. Receiver basics	*Mid-term break*
10.7		18. Receiver details	
17.7		19. Discussion	
24.7		20. Aerials	
31.7		21. Propagation	
7.8		22. Test equipment & measurements	
14.8		23. Regulations	
21.8		24. Trial test	
28.8		25. Test review (Exam Saturday).	
4.9		26. Examination review	

APPENDIX II

150 questions and answers.

Section A

The questions in this first section are reproduced from past Section A examination papers courtesy of the Radio Frequency Service, (RFS), of the Ministry of Commerce.

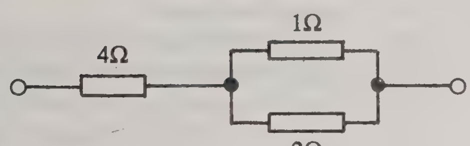


Figure 1

1. In Figure 1 the current flowing in the 2 ohm resistor is -

   A. Half of the current in the 1 ohm resistor.
   B. Twice the current in the 1 ohm resistor.
   C. Three quarters of the current in the 4 ohm resistor.
   D. Half of the current in the 4 ohm resistor.

2. The unit of energy is the -

   A. Watt.
   B. Ampere.
   C. Joule.
   D. Volt.

3. A hydrometer can be used to check the state of charge of a lead-acid cell since, as the cell becomes charged -

   A. The amount of sulphuric acid increases.
   B. The amount of sulphuric acid decreases.
   C. The amount of potassium hydroxide increases.
   D. The amount of potassium hydroxide decreases.

4. Which of the resistors below (each identified by its colour coding) would be nearest in value to a 4K7 ohm resistor?

   A. Orange violet orange.
   B. Yellow green red.
   C. Orange violet red.
   D. Yellow green orange.

5. If 2 watts of power is to be dissipated in a 9 ohm resistor, the required current would be approximately how many milliamperes?

   A. 220.
   B. 440.
   C. 470.
   D. 510.

6. The third harmonic of a transmitter has a wavelength that is -

   A. 3 times the intended output.
   B. Double that of the second harmonic.
   C. Unchanged from the intended output; only the frequency is different.
   D. One third of the intended output.

7. If the frequency of the alternating current applied to a capacitor is doubled, its capacitive reactance will be -

   A. Halved in value.
   B. Four times the original value.
   C. One quarter the original value.
   D. Also doubled.

8. The reactance of an ideal 50 pF capacitor at a frequency of 10 MHz is approximately -

A. 3.18×10^{-4} ohms.

B. 3.18×10^{-3} ohms.

C. 3.18×10^{2} ohms.

D. 3.18×10^{9} ohms.

9. With reference to a pure capacitor; which of the following is false?

A. Although current flow is opposed there is no power consumed.
B. Current lags the applied voltage by 90 degrees.
C. Current leads the applied voltage by 90 degrees.
D. The opposition to current flow is inversely proportional to the frequency of the current.

10. A resistor of 25 ohms in series with a capacitive reactance of 50 ohms is connected across a 50 volt AC power supply. To the nearest volt, what is the potential difference across the resistor?

A. 17. B. 19.
C. 22. D. 33.

11. When tuned for resonance the impedance of a parallel inductor and capacitor circuit is -

A. Capacitive.
B. Resistive.
C. Inductive.
D. Reactive.

12. The 'Q' or quality factor of a series tuned circuit is greatest when -

A. The resistive component is high when compared with the reactive component.
B. The reactive component is low when compared with the resistive component.
C. The reactive component is high when compared with the resistive component.
D. The capacitive reactance equals the inductive reactance.

13. Increasing the resistance in a series tuned circuit will increase:

A. The impedance at the resonance frequency.
B. The current flowing through the capacitor.
C. The voltage being developed across the inductor.
D. The effective "Q".

14. When comparing a ferrite cored inductor with an air cored inductor, assuming the same inductance for both, the ferrite cored inductor has -

A. More turns of wire.
B. A greater resistance.
C. A higher "Q" factor.
D. A greater bandwidth.

15. If the Q of a tuned circuit could be doubled, the 3 dB bandwidth of the arrangement would, relative to the original, be multiplied by a factor of -

A. 2.
B. A half.
C. The square root of 2.
D. 2 squared.

16. A transformer which has half as many turns on the primary as the secondary -

A. Will have a power transfer ratio of 1 : 2.
B. Will have a current ratio of 1 : 2.
C. Will have a voltage ratio of 1 : 2.
D. Will require for maximum power transfer a load impedance for the secondary which is half that of the primary.

17. With reference to ideal transformers; the impedance ratio is given by the -

A. Square of the turns ratio.
B. Inverse of the turns ratio.
C. Square root of the turns ratio.
D. Turns ratio.

18. In some power transformers a copper sheet is located between the primary and secondary windings. This sheet is normally earthed, and acts as a shield reducing the -

A. Capacitive coupling between primary and secondary.
B. Mutual inductance between primary and secondary.
C. Hum transfer between primary and secondary.
D. Eddy currents in the outside laminations.

19. To produce an output voltage the piezo-electric crystal in a crystal microphone must first -

A. Be distorted by sound waves.
B. Be placed within a magnetic field.
C. Be polarised by a direct voltage.
D. Be polarised by a direct current.

20. A germanium PNP transistor used in a common emitter class A amplifier stage would have a -

A. negative collector to emitter voltage.
B. Low output impedance.
C. High input impedance.
D. Positive base to emitter voltage.

21. Mounting a transistor on a block of aluminium provides -

A. Mechanical rigidity thereby improving frequency stability.
B. A low resistance connection to the collector.
C. A means for lowering the junction temperature.
D. A low resistance connection to the emitter.

22. A Darlington transistor has a high current gain by virtue of -

A. The voltage gain always being less than unity.
B. The base layer being extremely thin.
C. Combining two transistors so the gain multiplies.
D. Less signal being absorbed in the input.

23. Excessive plate dissipation in a tetrode RF amplifier valve may be caused by -

A. Insufficient control grid bias voltage.
B. Insufficient screen grid voltage.
C. Excessive resistance in the cathode circuit.
D. Excessive cathode bias voltage.

24. Which of the following are characteristics of a cathode follower -

A. The input and output impedances have the same value.
B. The input impedance is low compared with the output impedance.
C. The voltage gain is greater than unity.
D. The input impedance is high compared with the output impedance.

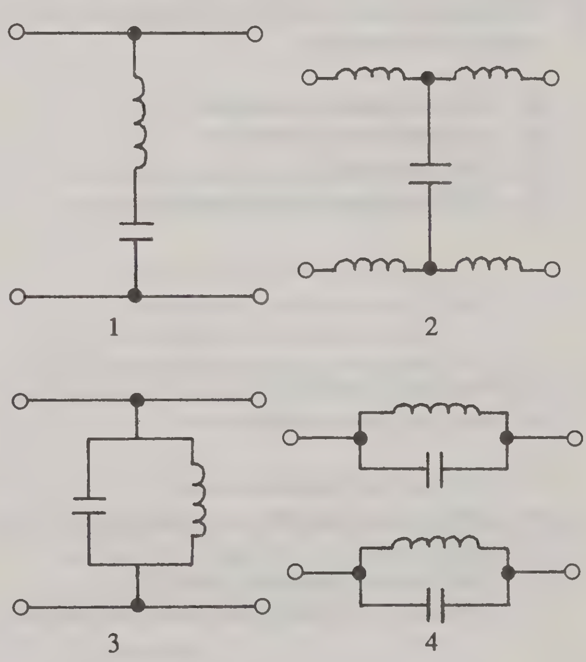


Figure 2.

25. Which of the circuits shown in Figure 2 are those of band stop filters? Assume the source and load impedances to be equal and resistive.

A. 1 as well as 2.
B. 2 as well as 3.
C. 3 as well as 4.
D. 4 as well as 1.

26. The purpose of an amplifier in an oscillator circuit is -

    A. To act as an oscillator buffer.
    B. To cancel phase shift.
    C. To produce an increasing output.
    D. To compensate for circuit losses.

27. Which of the following stages would you expect to find in a single sideband suppressed carrier transmitter?

    A. A balanced modulator.
    B. A class C RF power amplifier.
    C. A 45 degree audio phase shift network.
    D. A reactance modulator.

28. A 90 degree audio phase shift network would normally be found in a -

    A. Phase modulated transmitter.
    B. Pulse modulated transmitter.
    C. CW transmitter.
    D. SSB suppressed carrier transmitter.

29. In a frequency modulated signal, deviations from the carrier frequency depend on the -

    A. Amplitude of the audio signal.
    B. Ratio of amplitude to frequency of the audio signal.
    C. Frequency of the audio signal.
    D. Filtering out of the highest audio frequencies.

30. The modulation index of a frequency modulated transmission is expressed as the ratio between -

    A. The carrier frequency and the modulating frequency.
    B. The carrier frequency deviation and the modulating frequency.
    C. The carrier frequency and the frequency deviation.
    D. The modulating frequency and the carrier frequency.

31. Audio pre-emphasis is employed in the modulator stage of an FM transmitter to -

    A. Limit the audio bandwidth to conserve spectrum.
    B. Ensure that the transmitter is not overloaded.
    C. Improve the signal-to-noise ratio at the higher audio frequencies.
    D. Extend the audio bandwidth thereby improving the quality of the reproduced sound.

32. The final RF power amplifier stage of an FM transmitter is usually operated in -

    A. Class A.
    B. Class AB.
    C. Class B.
    D. Class C.

33. To increase the ratio of average power to peak envelope power in a single sideband suppressed carrier transmitter:

    A. Use a linear amplifier.
    B. Increase the bias on the final amplifier.
    C. Use a pi network in the output.
    D. Use amplitude limiting in the audio stage.

34. When a valve RF power amplifier is biased for a conduction angle of 360 degrees -

    A. Anode current flows for only part of the input cycle.
    B. Control grid RF voltage never cuts the valve off.
    C. The average grid voltage is twice cut-off voltage.
    D. RF power is produced at greatest efficiency.

35. In VHF and UHF transmitters, coil capacitor combinations used for tuning elements are often replaced by "striplines". These are -

    A. Transmission lines tuned to resonance.
    B. Coils with sufficient capacity between windings.
    C. Cavities resonant at the required frequency.
    D. Random lengths of coaxial cable.

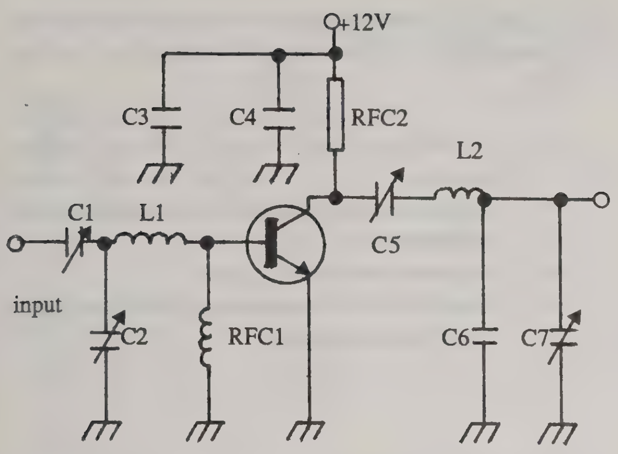


Figure 3

36. In the circuit shown in Figure 3 the purpose of L2, C5, C6 and C7 is to -

A. Bias the transistor.
B. Match the transistor collector to the load.
C. By pass the collector power supply.
D. Control oscillation frequency.

37. The component marked RFC1 in the circuit shown in Figure 3 is present to -

A. Permit self bias operation.
B. Prevent RF from entering the power supply.
C. Tune the input and output circuits.
D. Limit the average current.

38. To reduce harmonic interference from a transmitter output you would -

A. Feed the antenna via a low pass filter.
B. Ensure that the final amplifier operates in Class C.
C. Connect a parallel resistor-inductor network across the transmitter output.
D. Connect a capacitor in series with the feeder.

39. The generation of even harmonic energy in a radio frequency amplifier stage may be minimised by -

A. Using a Faraday screen.
B. Using a Class C amplifier.
C. Using a push-pull circuit.
D. Lowering the "Q" of the output tuned circuit.

40. Which of the following design features of a transmitter would assist in the reduction of harmonics in the output?

A. Class AB1 operation of the RF power amplifier.
B. Provision of a class C output stage.
C. A low pass filter between the audio amplifier and modulator.
D. Capacity coupling of the aerial to the anode circuit.

41. It is desirable to use a low pass filter in a transmitter output because -

A. Spurious emissions at higher frequencies will be greatly reduced.
B. Even harmonics will be suppressed much more than odd harmonics.
C. The Q at the working frequency may give some signal amplification.
D. A better load is presented to a mismatched antenna.

42. A simple direct conversion receiver can be very effective for SSB and CW reception. However -

A. It cannot receive weak stations.
B. It cannot reject audio image signals.
C. It cannot drive a loudspeaker.
D. It can receive one sideband only.

43. In an FM receiver the effect of sufficient signal arriving to start the limiter operating, thus reducing background noise, is described as -

A. Damping.
B. Squelch.
C. Quieting.
D. De-emphasis.

44. If a single conversion receiver is set to a station having a frequency of 3750 kHz and the receiver local oscillator frequency is 4200 kHz which of the following is known as the image frequency?

A. 2850 kHz.
B. 3750 kHz.
C. 4650 kHz.
D. 5550 kHz.

45. A superheterodyne receiver is less susceptible to image interference when it uses :

A. A low value of intermediate frequency.
B. A narrow bandwidth intermediate frequency amplifier.
C. A crystal filter immediately following the mixer.
D. Very selective tuned circuits preceding the first mixer.

46. A receiver specification "one microvolt to provide better than 20 dB signal-plus-noise to noise ratio in a passband of less than 3 kHz" would refer to the performance of -

A. Sensitivity.
B. Selectivity.
C. Stability.
D. Image rejection.

47. To reproduce weak signals satisfactorily which of the following is a necessary feature for a receiver?

A. A high audio output power capability.
B. A high value for the intermediate frequency.
C. A wide IF bandwidth.
D. A low noise factor.

48. There is little point improving the noise figure of a high frequency receiver to a value that would be required for a very high frequency receiver because-

A. HF receivers are generally fitted with noise limiters.
B. HF receivers are narrow band whereas VHF receivers are often wideband.
C. Noise due to thermal agitation is much lower at HF than at VHF.
D. Atmospheric noise is much higher at HF than at VHF.

49. The factor which places a practical limit on the weakest signal that a receiver will respond to is the -

A. Level of noise generated by the IF amplifier section.
B. Frequency of the IF amplifier.
C. Level of noise generated by the RF amplifier section.
D. Frequency of the local oscillator.

50. Some HF receivers have a 20 dB switchable attenuator in the RF input. The main use of this is -

A. To reduce breakthrough of the image frequency.
B. To reduce the audibility of "woodpecker" interference.
C. To reduce the dynamic range.
D. To reduce intermodulation interference from strong adjacent signals.

51. Reducing the final intermediate frequency bandwidth of a receiver will -

A. Reduce the immunity from RF stage blocking.
B. Reduce the lowest audio frequency that will be reproduced.
C. Reduce the noise power at the detector output.
D. Reduce the immunity from mixer cross modulation.

52. To be able to discriminate between closely spaced stations a receiver should use -

A. RF stages with manual gain control.
B. A high value of intermediate frequency.
C. Double conversion.
D. A narrow band filter in the IF stage.

53. Cascading 2 identical crystal filters in the IF section of a receiver would have the main effect of -

A. Sharpening the selectivity.
B. Doubling the input impedance.
C. Reducing the ultimate rejection.
D. Flattening the passband response.

54. The main purpose of a limiter stage in the intermediate frequency amplifier of a frequency modulation receiver is :

A. To limit the frequency response.
B. To stop the AGC detector being overloaded.
C. To provide audio limiting.
D. To remove amplitude variations from the signal.

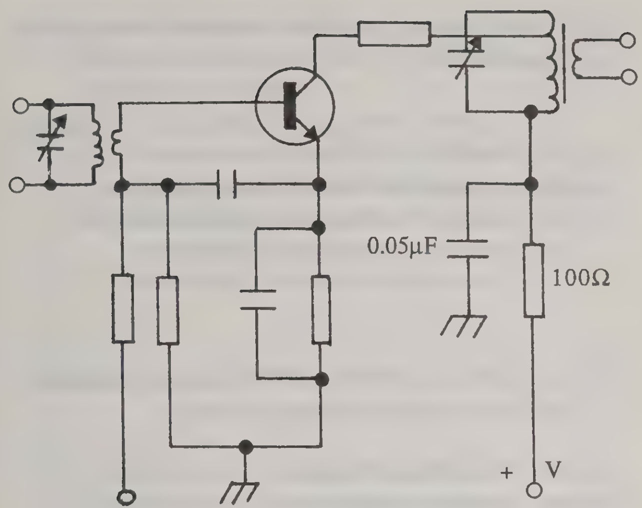


Figure 4.

55. In Figure 4 the 100 ohm resistor and 0.05 μF capacitor act to -

A. Develop a bias voltage for the base of the transistor.
B. Suppress parasitic oscillations.
C. Form a load for the transistor collector circuit.
D. Minimise signal currents flowing in the power supply.

56. The circuit shown in Figure 4 represents :

A. A product detector.
B. An FM discriminator.
C. An IF amplifier.
D. A mixer-oscillator.

57. A product detector -

A. Is usually found in an FM receiver.
B. Will only respond to strong signals.
C. Requires the application of the agc voltage to prevent self oscillation on strong signals.
D. Unlike an envelope detector, causes little distortion to weak signals.

58. Reciprocal mixing in a receiver is related to -

A. The purity of the local oscillator.
B. The breakthrough of lower sideband signals onto upper sideband signals.
C. Whether there are more IF stages than RF stages.
D. The suppression of image responses.

59. The characteristic impedance of an air-spaced coaxial transmission line depends mainly on -

A. The velocity factor of the transmission line.
B. The diameter of the outer conductor as a fraction of a wavelength.
C. The ratio of the conductor diameters.
D. The absolute size of the inner conductor.

60. A Smith Chart is useful for -

A. Designing Yagi antennas.
B. Working out harmonic and intermodulation products.
C. Working out transmission line relationships.
D. Designing Pi coupler tank circuits.

61. When a transmission line is correctly matched to an antenna -

A. Minimum power is delivered to the antenna.
B. Maximum power is delivered to the antenna.
C. There will be no standing waves formed on the antenna.
D. The standing wave ratio is zero.

62. When the radio frequency energy is fed through a transmission line having an impedance of 50 ohms to a 50 ohm non-inductive resistor :

A. The energy is dissipated equally by the resistor and the transmission line.
B. Most of the energy will be dissipated as heat by the resistor.
C. The radiated energy will be greatest.
D. Most of the energy will reflect from the resistor.

63. If one wavelength transmission line is terminated in a short circuit then -

A. The voltage is high at the shorted end.
B. The current is low at the shorted end.
C. The current is high at a point one half wavelength from the shorted end.
D. The voltage and current are in phase all along the line.

64. An electrical quarter-wavelength of transmission line is left open circuited at its far end. The impedance at the input will appear to be predominantly -

A. A high resistance.
B. Capacitive.
C. Inductive.
D. A low resistance.

65. The standing-wave ratio of an antenna feeder system can be derived from the -

A. Transmitted wavelength and the feeder length.
B. RF voltage and current when measured at the same point on the feeder.
C. Antenna feed point impedance and the feeder impedance.
D. Antenna length and the feeder length.

66. The VSWR on a transmission line placed between a transmitter and antenna can be adjusted by -

A. Changing the transmitter's output impedance.
B. Changing the length of transmission line.
C. Placing an antenna tuner at the transmitter end.
D. Changing the antenna's input impedance.

67. The difference between tuned and untuned transmission lines is that -

A. The tuned line length is independent of frequency.
B. The untuned line is an integral number of quarter wavelengths long.
C. The tuned line operates with a higher VSWR.
D. The untuned line is made of balanced TV twinlead.

68. A balanced transmission line matched to a balanced resistive load will radiate little RF energy because -

A. The standing wave ratio is very low.
B. The currents in each conductor are, at any point, equal and opposite.
C. There is too much capacitance between the conductors.
D. In the matched condition, the conductors carry no RF current.

69. Radio frequency radiation from the shielding of a coaxial cable -

A. Cannot occur as the shield is at ground potential.
B. Is caused by 'leaky' internal insulation.
C. Occurs when standing waves are present.
D. Will occur if the load is balanced.

70. A 75 ohm pi section matching pad has shunt arms that have a resistance that is always -

A. Greater than 75 ohms.
B. Less than 75 ohms.
C. Equal to 75 ohms.
D. Equal to 150 ohms.

71. An antenna's radiation resistance may be described as -

A. A fictitious resistance that accounts for the power radiated from the antenna.
B. The resistance of the ionosphere to the passage of electromagnetic waves.
C. The resistance of the material from which the antenna is made.
D. The resistance of the feeder cable.

72. The most effective way of improving the long distance communications efficiency of a horizontally polarised dipole antenna would be -

A. To use a 2 wire balanced transmission line.
B. To use a heavier gauge multistrand copper conductor.
C. To increase its height above ground.
D. To use a coaxial cable transmission line and a balun.

73. If the feed point could be varied anywhere along a half-way dipole it would be found that the impedance -

A. Varies from low at the ends to high at the centre.
B. Varies from high at the ends to low at the centre.
C. Is uniform along its length.
D. Is purely resistive.

74. To resonate, the length of a practical half wave dipole when compared to a freespace half wavelength, should be -

A. Made shorter because of end effect capacitance.
B. Made longer because of end effect capacitance.
C. Made longer because wire has a finite thickness.
D. Made longer due to self inductance.

75. You intend to centre feed a half wave antenna. To obtain the lowest voltage standing wave ratio which transmission line would you use?

A. 600 ohm open wire line.
B. 300 ohm parallel ribbon line.
C. 70 ohm coaxial cable.
D. 50 ohm coaxial cable.

76. At the base of the radiating element of a quarter wave ground plane antenna -

A. RF current and RF voltage are highest.
B. RF current and RF voltage are lowest.
C. RF current is highest and RF voltage is lowest.
D. RF current is lowest and RF voltage is highest.

77. To operate a quarter-wave antenna below its design frequency it is desirable to -

A. Add a capacitor in series with the antenna.
B. Add an inductor in series with the antenna.
C. Fit a balun between the antenna and its feed line.
D. Add a counterpoise earth system to the antenna.

78. A vertical antenna can be used to -

A. Obtain low angle radiation.
B. Overcome television or broadcast interference.
C. Obtain minimum groundwave.
D. Obtain maximum high angle radiation.

79. A three element yagi antenna is designed to have -

A. A reflector shorter than resonance and a director longer than resonance.
B. A director shorter than resonance and a reflector longer than resonance.
C. A reflector and director both shorter than resonance but unequal spacing.
D. A reflector equal to resonance and a director shorter than resonance.

80. A directional antenna's front to back ratio is the ratio of -

A. The length of the front element to the back element.
B. The power radiated in the forward direction to that in the opposite direction.
C. Forward power to reverse power when transmitting.
D. The power radiated when transmitting to the power picked up when receiving.

81. To reduce harmonic radiation from an antenna -

A. Use a balun with a coaxial transmission line.
B. Use a transmission line that is electrically one half wavelength long.
C. Feed the antenna via a low pass filter.
D. Use a balun with an open wire transmission line.

82. The solar cycle, as evidenced by a rise and fall of the smoothed mean Zurich sunspot numbers, has an average length corresponding to about.

A. 3 years.
B. 7 years.
C. 11 years.
D. 15 years.

83. Which of the following ionospheric parameters can be determined by sending a wave vertically up and measuring the time it takes to return to earth ?

A. Virtual height.
B. Critical angle.
C. Sporadic E.
D. Ionosphere constant.

84. Although excellent communication can occur at the MUF, communmication usually takes place at a lower frequency because -

A. There is less signal lost due to absorption.
B. There is less chance of band closure due to slight variations in the ionosphere.
C. A lower radiation angle can more easily be achieved.
D. The virtual height of the ionosphere is greater.

85. The critical frequency for an ionsopheric layer is -

A. The lowest frequency that can be transmitted over a line of sight path.
B. The highest frequency that will just be received over the horizon.
C. The highest frequency that can be transmitted over a line of sight path.
D. The highest frequency which, when transmitting vertically upwards, is returned by that layer.

86. The most suitable amateur band for reliable communication over a 2000 kilometre daylight path would be :

A. 80 metres.
B. 20 metres.
C. 6 metres.
D. 2 metres.

87. The earth's ionosphere consists of several layers whose presence or absence changes from day to night. Given that the first letter in each of the groups below indicates the lowest layer, which of the following is correct?

A. Day F E D.
B. Night D E F .
C. Day D E F1 F2.
D. Night F E.

88. For the same transmitter power morse can generally maintain radio contact over a greater distance than with speech because -

A. Propagation does not necessarily follow a great circle path.
B. The CW portions of amateur bands have better propagation characteristics.
C. Ionospheric absorption is not so great with constant level signals.
D. The receiver bandwidth required can be much less.

89. A need exists for an instrument that will measure direct voltages up to a maximum of 200 V. A 0-1mA meter having an internal resistance of 100 ohms is available. Which of the following resistors should be connected to make the voltmeter?

A. 19900 ohms.
B. 20000 ohms.
C. 199900 ohms.
D. 200000 ohms.

90. The reading on a simple rectifier type multi-range test meter when set to an alternating voltage range is always -

A. The RMS value of the waveform being measured.
B. Dependent upon the shape of the wave being measured.
C. The peak value of the waveform being measured.
D. The square root (1.414) of the peak value of the waveform being measured.

91. A dip oscillator (dip meter) can be used to measure the -

A. Drive power required by a linear amplifier stage.
B. Resonance frequency of a tuned circuit.
C. Accuracy of a digital frequency counter.
D. Distortion in a linear amplifier stage.

92. Which of the following meters would you use to measure radio frequency currents?

A. A moving coil ammeter.
B. A frequency meter.
C. A rectifier type voltmeter.
D. A thermocouple ammeter.

93. A wavemeter is a simple device which allows an approximate measurement of -

A. Capacitance.
B. Wave impedance.
C. Wave number.
D. Frequency.

94. Digital frequency counters with a readout specification of plus or minus one digit cannot claim greater precision because -

A. The gating period is never synchronised with the signal being measured.
B. The timebase accuracy is never better than 1Hz.
C. Propagation delay within the counter is never zero.
D. A pre-scaler can never have a precise ratio.

95. To test the output power of any transmitter on any frequency a dummy load should be -

A. Purely capacitive.
B. Purely resistive.
C. Purely inductive.
D. A combination of inductance, resistance and capacitance.

96. When comparing the toroidal transformer and short coupled transmission line types of in-line SWR meter -

A. The latter using a distributed line is unable to operate at HF.
B. The latter relies on inductive coupling between transmission lines.
C. The former being more compact is better suited to use at VHF.
D. The former has a sensitivity which is independent of frequency.

97. A noise bridge and an HF receiver are useful for -

A. Checking the value of wire wound resistors.
B. Evaluating power line interference.
C. Adjusting VHF preamplifiers.
D. Measuring RF impedances.

98. Which of the following cathode ray tube elements is most negative with respect to the positive supply terminal?

A. The control grid.
B. The focusing electrode.
C. The accelerating electrode.
D. The cathode.

99. Which of the following would cause the signal image on an oscilloscope screen to be held stationary?

A. Crystal control of the timebase generator.
B. Make the level of the X and Y signals equal.
C. Synchronisation of the timebase generator by the incoming wave.
D. By arranging 180 degree phase shift to the timebase.

100. Which of the following statements apply to linear amplifier stages?

A. It is the only amplifier that is 100 percent efficient.
B. The shape of the output waveform is similar to that of the input waveform.
C. The stage's active device conducts for less than 50 percent of the input waveform.
D. A 2-tone signal generator is needed to measure the amplifier's peak envelope power.

Section B

The remaining qestions are reproduced from past Section B examination papers courtesy of RFS.

101. An Amateur station is a radio station which is-

   A. Licensed by the Radio Frequency Service to operate in the amateur frequency bands.
   B. Owned and operated by a person who is not engaged professionally in radio communications.
   C. Used exclusively to provide two-way radio communications in connection with activities of amateur sporting organisations.
   D. Used primarily for emergency communications in floods, bushfires and similar disaster situations.

102. How many grades of amateur operators certificates are issued by this administration?

   A. Four
   B. One
   C. Two
   D. Three

103. At what minimum age can a person be issued with an amateur operators certificate?

   A. At any age.
   B. 14 years.
   C. 16 years.
   D. 18 years.

104. The morse code speed (in words per minute) to be attained by General Amateur Certificate candidates is-

   A. 10
   B. 8
   C. 12
   D. 5

105. Provided annual licence renewal fees are paid the holder of an amateur operators certificate may hold an apparatus licence for-

   A. One year only.
   B. Two years only.
   C. Five years only.
   D. Any period.

106. When an Amateur Radio Operator does not desire to renew his licence he is required to advise the Radio Frequency Service and-

   A. Destroy the licence.
   B. Retain the licence.
   C. Return the licence.
   D. Receive a refund.

107. Amateur radio apparatus may be established by-

   A. A licenced CB operator.
   B. The holder of an Amateur Operators Certificate.
   C. The holder of a Restricted RT Operators Certificate.
   D. The operator of a small ship radio apparatus.

108. An amateur radio station may be established by-

   A. A licenced CB operator.
   B. The holder of an Amateur Operators Certificate.
   C. The holder of a TV receiving licence.
   D. The operator of a small ship radio station.

109. In the event of an amateur radio station being moved to a location other than that shown on the station licence, the licensee must advise the Radio Frequency Service in writing-

   A. Within 7 days.
   B. Within 1 year.
   C. Within 14 days.
   D. Within 1 month.

110. An amateur radio operator is informed that his transmissions are causing interference to a neighbour's TV. The first action the amateur should take is to-

A. Continue transmission to determine corrective measures.
B. Continue transmission until fault in transmitter is rectified.
C. Cease transmission and immediately notify a Technical Service Officer.
D. Continue transmission until fault in TV is rectified.

111. Before making a test transmission on the air, an amateur operator should-

A. Listen on the proposed frequency.
B. Fit an artificial antenna.
C. Tune the transmitter correctly.
D. Inform all other stations on the frequency.

112. Before an amateur radio operator makes a brief test transmission, he should-

A. Check that the frequency is not already in use.
B. Ensure that the test does not exceed one minute.
C. Give his allocated callsign at least every ten minutes.
D. Fit an artificial aerial to the transmitter.

113. When transmitting, an Amateur Operator is required to transmit his allocated callsign-

A. Every 5 minutes during the session.
B. At least once per hour during the course of transmission.
C. Every 10 minutes during the session.
D. Whenever another operator is about to transmit.

114. Which of the following communications is within the terms of an amateur apparatus licence?

A. Fast-scan TV on the band 14000-14350 kHz.
B. Technical communication with other amateur licensees.
C. The transmission of a public telephone link on amateur bands.
D. Cross-band working with a Citizen Band operator.

115. Which of the following would not be acceptable to the RFS under normal conditions?

A. A contact between a Novice operator and a Citizens Radio operator on 26 MHz.
B. A contact between a Novice operator and the holder of an amateur operators limited licence.
C. A contact between a small ship and a Novice Amateur operator under emergency conditons.
D. A contact between an amateur operator and any emergency service during an earthquake disaster situation.

116. The maximum peak envelope power (in watts) allowable to Amateur licencees of General Grade is-

A. 30
B. 50
C. 150
D. 400

117. What is the maximum power permitted for amateur operation?

A. 200 watts.
B. 400 watts.
C. 50 watts.
D. No limit.

118. Which of the following item is NOT required for inclusion in an amateur station logbook-

A. Date and time of each transmission.
B. Names and addresses of stations worked.
C. Frequencies on which contacts have been made.
D. Modes of transmission used.

119. Which of the following documents need not be shown to a Radio Inspector during an inspection of an amateur radio station?

A. Station log book (if kept).
B. Amateur Operator's certificate.
C. Amateur station licence.
D. Declaration regarding secrecy of radio communication.

120. If you find a person lying on a workshop floor still in contact with a "live" wire, which of the following steps would you take FIRST?

A. Commence "mouth to mouth" artificial respiration.
B. Proceed with heart massage immediately.
C. Remove the "live" wire from contact with the victim.
D. Apply "mouth to mouth" respiration and external heart massage simultaneously.

121. Which of the following frequency bands is not authorised for use by New Zealand Amateur Radio licensees?

A. 25.100 to 25.300 MHz.
B. 3.5 to 3.7 MHz.
C. 28.00 to 29.70 MHz.
D. 1800 to 1860 kHz.

122. The band limits of the 80M amateur band are-

A. 3000 - 3900 kHz.
B. 2500 - 4000 kHz.
C. 3500 - 3900 kHz.
D. 3450 - 4200 kHz.

123. Amateur operation in the band 7.100 - 7.300MHz is shared with-

A. The land-Mobile Service.
B. The Broadcasting Service.
C. No other service.
D. The Fixed Service.

124. Which of the following Amateur bands is often called "the 15 metre band"?

A. 1800 to 1860 kHz.
B. 28.00 to 29.70 MHz.
C. 14.00 to 14.35 MHz.
D. 21.00 to 21.45 MHz.

125. To which transmitting mode does the symbol "F3E" refer?

A. Facsimile with direct carrier modulation.
B. Four channel multiplex telegraphy.
C. Frequency modulation using speech.
D. Phase modulated telegraphy.

126. Which of the following signals are radiated by a "J3E emission"?

A. A carrier and two sidebands.
B. One sideband and no carrier.
C. Two sidebands and no carrier.
D. Lower sideband and carrier.

127. Of the following emission classifications which one identifies SSB?

A. J3E.
B. A3E.
C. F3E
D. A1A.

128. Which of the following group of significant letters(s) identifies an operator from the USA?

A. G
B. ZL
C. W
D. J

129. Which of the following group of significant letter(s) identifies an operator from the Cook Islands?

A. ZM.
B. ZA.
C. ZK.
D. ZS.

130. Which of the callsigns would relate to a radio station in the Broadcasting Service?

A. ZL2HF.
B. ZLC.
C. ZK-CKF.
D. 2YA.

131. Which of these callsigns would relate to a radio apparatus in the Maritime Mobile Service?

A. ZL2HF.
B. ZLC5.
C. ZK-CKF.
D. ZMX4423.

132. The morse code signal SOS is sent by an operator who-

A. Has an urgent business message.
B. Is reporting grave and imminent danger to life.
C. Makes a report regarding a shipping hazard.
D. Is sending important weather information.

133. The abbreviation "TVI" means-

A. Tuvalu Island.
B. Television Interference.
C. Thanks very much.
D. Televison One.

134. The abbreviation "PEP" means-

A. Provisional extra potential.
B. Poor emergency position.
C. Parasitic elimination policy.
D. Peak envelope power.

135. If an amateur radio operator sends "CQ DX" while making a general call, he-

A. Wishes to contact a German amateur station.
B. Invites reply from members of a DX club.
C. Expects a reply from local amateur operators.
D. Is not interested in calls from local radio amateurs.

136. Which of the following gives the meaning of the "Q code" signal "QRN?"?

A. "Are you troubled by static?"
B. "What is the exact time?"
C. "I am suffering from interference".
D. "Shall I cancel the last message received?"

137. Which of the following does "QRS" mean?

A. "I am calling another station."
B. "Please reduce your sending speed."
C. "I am receiving your signals at strength 5."
D. "I shall reduce power."

138. What does "QRU" mean in a Morse code transmission?

A. "Have you anything for me?"
B. "I have nothing for you".
C. "Are you ready?".
D. "What is my exact frequency?"

139. The Q code signal "QRV?" means-

A. "Are you ready?"
B. "I am about to send a test signal."
C. "Please send a series of Vs."
D. "Your signals are fading."

140. Which of the following does "QSA 5" mean?

A. "I am calling another station."
B. "Please reduce your sending speed."
C. "I am receiving your signals at strength 5."
D. "I shall reduce power."

141. If the operator with which you are in communication sends "QSB" in morse code, he means-

A. That your signals are fading.
B. That his signals are fading.
C. That atmospherics are making reception difficult.
D. That a nearby transmitter is causing interference.

142. The "Q" code signal "QSL" means-

A. "Your frequency is varying".
B. "Your signals are unreadable".
C. "You may resume normal working".
D. "I acknowledge receipt".

143. What is the meaning of the signal "QSO ZL1NP?"?

A. "Have you any message for ZL1NP?"
B. "Are you receiving interference from ZL1NP?"
C. "Can you communicate with ZL1NP?"
D. "Are you monitoring signals from ZL1NP on this frequency?"

144. The code signal "QSY 3575" means-

A. "Change to transmission on 3575 kHz".
B. "Please handle emergency traffic on 3575 kHz".
C. "Your exact transmitting frequency is 3575 kHz".
D. "Send a series of V's on 3575 kHz".

145. The "Q" code "QTH" is often heard- it means-

A. Increase your power.
B. Change your frequency.
C. The time is .....
D. The location is .....

146. Which of these "Q" codes relates to interference?

A. QSV.
B. QRH.
C. QTH.
D. QRM.

147. An amateur operator wants another station to check his exact transmitting frequency. He should send the "Q code" signal-

A. QRG?
B. QRH?
C. QSA?
D. QRK?

148. What "Q code" signal should be send as an instruction to a station to cease transmitting?

A. QRK?
B. QRT
C. QSX
D. QUM

149. During a CW contact, which "Q code" signal would you transmit to find out if the other operator is experiencing interference from another station?

A. QSV?
B. QRH?
C. QTH?
D. QRM?

150. Which of the following "Q code" signals means "WHO IS CALLING ME?"?

A. QRQ?
B. QRS?
C. QRK?
D. QRZ?

Answers

Section A-

These are not official answers, but are those that have been determined by the author.

1.	A	21.	C	41.	A	61.	B	81.	C
2.	C	22.	C	42.	B	62.	B	82.	C
3.	A	23.	A	43.	C	63.	C	83.	A
4.	B	24.	D	44.	C	64.	D	84.	B
5.	C	25.	D	45.	D	65.	C	85.	D
6.	D	26.	A	46.	A	66.	D	86.	B
7.	A	27.	A	47.	D	67.	C	87.	C
8.	C	28.	D	48.	D	68.	B	88.	D
9.	B	29.	A	49.	C	69.	D	89.	C
10.	C	30.	B	50.	D	70.	A	90.	B
11.	B	31.	C	51.	C	71.	A	91.	B
12.	C	32.	D	52.	D	72.	C	92.	D
13.	A	33.	D	53.	A	73.	B	93.	D
14.	C	34.	B	54.	D	74.	A	94.	A
15.	B	35.	A	55.	D	75.	C	95.	B
16.	C	36.	B	56.	C	76.	C	96.	D
17.	A	37.	A	57.	D	77.	B	97.	D
18.	A	38.	A	58.	A	78.	A	98.	A
19.	A	39.	C	59.	C	79.	B	99.	C
20.	A	40.	A	60.	C	80.	B	100.	B

Answers

Section B-

These are not official answers, but are those that have been determined by the author.

101.	A	111.	A	121.	A	131.	D	141.	A
102.	D	112.	A	122.	C	132.	B	142.	D
103.	A	113.	B	123.	B	133.	B	143.	C
104.	C	114.	B	124.	D	134.	D	144.	A
105.	D	115.	A	125.	C	135.	D	145.	D
106.	C	116.	D	126.	B	136.	A	146.	D
107.	B	117.	B	127.	A	137.	B	147.	A
108.	B	118.	B	128.	C	138.	B	148.	B
109.	A	119.	D	129.	C	139.	A	149.	D
110.	C	120.	C	130.	D	140.	C	150.	D

APPENDIX III

Amateur frequency allocations

The following Amateur Radio Station frequency allocation list is reprinted from the New Zealand Radio Frequency Service pamphlet RT4, amended June 1989:

Amateur frequency allocation chart-

Frequency band	Class
1800 to 1950 kHz (Notes 3 and 6)	General
3.50 to 3.90 MHz (Notes 1 and 3)	General
3.525 to 3.625 MHz (Notes 1 and 3)	Novice
7.00 to 7.10 MHz (Notes 1, 2 and 10)	General
7.10 to 7.30 MHz (Notes 7 and 10)	General
10.10 to 10.15 MHz (Notes 1, 3, 6 and 10)	General
14.00 to 14.35 MHz (Notes 1, 2 and 10)	General
18.068 to 18.168 MHz (Notes 1 and 10)	General
21.00 to 21.45 MHz (Notes 1, 2 and 10)	General
21.10 to 21.20 MHz (Notes 1 and 2)	Novice, General
24.89 to 24.99 MHz (Notes 1, 2 and 10)	General
27.12 MHz (Notes 4 and 8)	all
28.00 to 29.70 MHz (Notes 2 and 10)	General
28.10 to 28.60 MHz (Note 2)	Novice
50.00 to 50.15 MHz (Note 9)	Limited, General.
51.00 to 53.00 MHz (Note 3)	Limited, General
144.0 to 146.0 MHz (Notes 1 and 2)	Limited, General
146.0 to 148.0 MHz (Note 3)	Limited, General
430 to 449.75 (Notes 2 and 3)	Limited, General
610 to 622 MHz (Note 3)	Limited, General
1.24 GHz to 1.30 GHz (Notes 2 and 3)	Limited, General
2.30 GHz to 2.45 GHz (Notes 2, 3 and 4)	Limited, General
3.30 GHz to 3.50 GHz (Notes 2 and 3)	Limited, General
5.65 GHz to 5.85 GHz (Notes 2, 3 and 4)	Limited, General
10.0 to 10.5 GHz (Notes 2 and 3)	Limited, General
24.00 to 24.05 GHz (Notes 2 and 4)	Limited, General
24.05 to 24.25 GHz (Notes 3 and 4)	Limited, General
47.0 to 47.2 GHz (Note 2)	Limited, General
75.5 to 76.0 GHz (Note 2)	Limited, General
76.0 to 81 GHz (Notes 2 and 3)	Limited, General
119.98 to 120.02 GHz (Note 3)	Limited, General
142 to 144 GHz (Note 2)	Limited, General
144 to 149 GHz (Notes 2 and 3)	Limited, General
241 to 248 GHz (Notes 2 and 3)	Limited, General
248 to 250 GHz (Note 2)	Limited, General
275 GHz to 400 GHz (Note 5)	Limited, General

The class of emission used from an amateur station should be selected in the light of the total available bandwidth for all users and shall be in accordance with current operating practice.

Transmission of morse code by Limited Grade operators is permitted.

Notes

1. The bands at 3.5 MHz, 7.0 MHz, 10.0 MHz, 14.0 MHz, 18.0 MHz, 21.0 MHz, 24.890 MHz and 144 MHz are available for use by all stations at times of natural disaster in connection with international relief operations.

2. The bands 7.00 to 7.1 MHz; 14.0 to 14.25 MHz, 21.00 to 21.45 MHz; 24.890 to 24.990 MHz; 28.0 to 29.7 MHz; 144 to 146 MHz; 435 to 438 MHz; 1260 to 1270 MHz (earth-to-space direction only); 2.4 to 2.45 GHz; 3.40 to 3.41 GHz; 5.65 to 5.67 GHz (earth-to-space direction only); 5.83 to 5.85 GHz (space-to-earth direction only); 10.45 to 10.5 GHz; 24.0 to 24.05 GHz; 47.0 to 47.2 GHz; 75.5 to 81 GHz; 142 to 149 GHz, and 241 to 250 GHz mayalso be used for amateur satellite communications.

3. This band is shared either on an equal or on a secondary basis with other radio services. Amateur use is on a strict non-interference basis to stations of these other services.

4. The frequencies 27 12 MHz, 2.45 GHz. 5.8 GHz; and 24.125 GHz are designated for industrial, scientific and medical (ISM) purposes with emissions confined within ±163kHz, ±50MHz, ±75MHz, and ±125MHz respectively of these frequencies. Amateur stations operating within these limits must accept interference from ISM equipment.

5. The band 275 to 400GHz is allocated for use by amateur stations on a temporary and non-interference basis for experimentation and development purposes.

6. Until further notice the following spot frequencies are not to be used: 1800kHz (±3kHz), 1860kHz (±3kHz), 10.130MHz (±3kHz). The frequencies of 1850kHz - 1950kHz should be used with caution as they are also used for navigation purposes

7. Operation is on a strictly non-interference basis to broadcasting services.

8. Telecontrol and telemetry operation only Power not to exceed 5 watts

9. The band 50 - 50.15 MHz is allocated for temporary use on a non-interference basis to existing services. Operation is only permitted outside television programme hours. *(Refer authors note page 23.6)*

10. Operation on these bands by General Grade operators is not permitted during the first 12 months of obtaining the qualification. This does not apply to the sub band 21.10 MHz to 21.20 MHz.

APPENDIX IV

Abbreviations

Abbreviations for c.w. work

AA	All after
AB	All before
ABT	About
AGN	Again
BCNU	Be seeing you
BK	Break
BN	All between; been
B4	Before
C	Yes
CFM	Confirm; I confirm
CK	Check
CL	Closing down
CUAGN	See you again
CUL	See you later
DE	From
ER	Here
ES	And
FB	Fine business; excellent
FER	For
GB	Goodbye
GE	Good evening
GM	Good morning
GN	Good night
GUD	Good
HI	Laughter
HR	Here
HW	How
K	Invitation to transmit
NW	Now
OB	Old boy
OG	Old girl
OM	Old man
OP	Operator
PSE	Please
PWR	Power
RFI	Radio frequency interference
RPT	Repeat; I repeat
RX	Receiver
SIG	Signal
SRI	Sorry
TFC	Traffic
TNX; TKS	Thanks
TVI	Television interference
TX	Transmitter
U	You
UR	Your
URS	Yours
VY	Very
WA	Word after
WB	Word before
WKD	Worked
WX	Weather

General abbreviations

ATV	Amateur television
BC	Broadcast
BUG	Semi-automatic key
CB	Citizens band
CD	Civil defence
CQ	Calling any station
DX	Long distance
IARU	International Amateur Radio Union
IRC	International reply coupon
LCD	Liquid crystal display
NZART	New Zealand Association of Radio Transmitters.
R/C	Radio control
RI	Radio inspector
RIG	Station equipment
RIT	Receiver incremental tuning
RTTY	Radio teletype
SKED	Schedule
SSTV	Slow scan television
SWL	Shortwave listener
VSWR	Voltage standing wave ratio
WARC	World Administrative Radio Conference
XYL	Wife
XTAL	Crystal
YL	Young lady
73	Best regards
88	Love and kisses

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